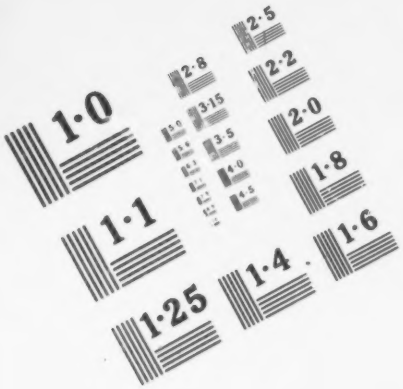
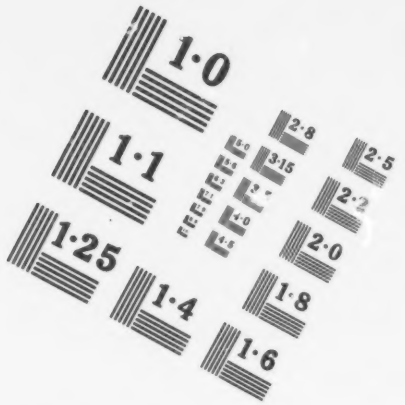
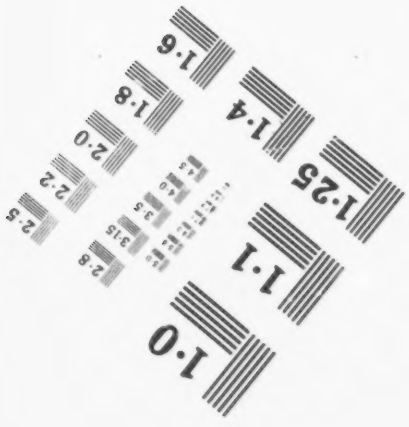
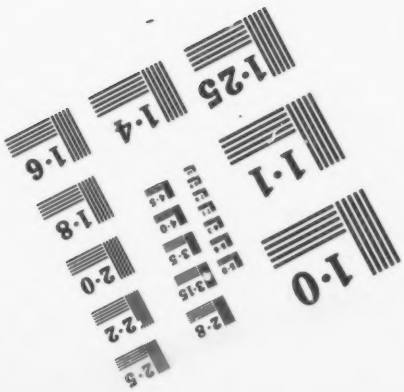




MICROPUBLISHED
BY
READEX MICROPRINT CORP.
NEW CANAAN, CT
USA

24X





B329/2/989

BAUXITE, ALUMINA, AND ALUMINUM

By Errol D. Sehnke and Patricia A. Plunkert

1989

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

I 28.37/a:

READEX FICHE best copy available

BAUXITE, ALUMINA, AND ALUMINUM

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

November 1990

Contents

Bauxite and Alumina 1
Legislation and Government Programs 1
Production 1
Consumption and Uses 2
Prices 2
Foreign Trade 3
World Review 4
Capacity 5
Australia 5
Brazil 6
Canada 6
Germany, Federal Republic of 6
Guinea 6
Guyana 6
India 6
Italy 6
Jamaica 6
Suriname 7
Sweden 7
Venezuela 7
Current Research 7
Outlook 8
Aluminum 8
Legislation and Government Programs 9
Production 9
Primary 9
Secondary 11
Consumption 11
Stocks 13
Prices 13
Foreign Trade 14
World Review 16
Capacity 16
Algeria 16
Australia 16
Bahrain 16
Brazil 16
Canada 18
China 18
Dubai 18
Indonesia 18
Korea, Republic of 18
Netherlands 18
Norway 18
Saudi Arabia 19
South Africa, Republic of 19
Switzerland 19
Taiwan 19
U.S.S.R. 19
United Kingdom 19
Venezuela 19
Current Research 19
Outlook 19
Background 21
Definitions, Grades, and Specifications 21
Geology-Resources 22
Technology 25
Exploration 25
Mining 26
Beneficiation 26
Alumina Production 26
Smelting 27
Primary Aluminum Production 27
Superpurity Aluminum Processing 28
Recycling 28
Economic Factors 29

Tables

Table 1.—Salient Bauxite Statistics 1
Table 2.—Mine Production of Bauxite and Shipments From Mines and Processing Plants to Consumers in the United States 2
Table 3.—Percent of Domestic Bauxite Shipments, by Silica Content 2
Table 4.—Production and Shipments of Alumina in the United States 2
Table 5.—Capacities of Domestic Alumina Plants, December 31 3
Table 6.—U.S. Consumption of Bauxite, by Industry 3
Table 7.—U.S. Consumption of Crude and Processed Bauxite 3
Table 8.—Production and Shipments of Selected Aluminum Salts in the United States in 1988 3
Table 9.—Stocks of Bauxite in the United States, December 31 4
Table 10.—Stocks of Alumina in the United States, December 31 ... 4
Table 11.—Average Value of U.S. Imports of Crude and Dried Bauxite 4
Table 12.—Market Quotations on Alumina and Aluminum Compounds 4
Table 13.—U.S. Exports of Alumina, by Country 4
Table 14.—U.S. Imports for Consumption of Bauxite, Crude and Dried, by Country 5
Table 15.—U.S. Imports for Consumption of Calcined Bauxite, by Country 5
Table 16.—U.S. Imports for Consumption of Alumina, by Country 5
Table 17.—Bauxite: World Production, by Country 7
Table 18.—World Annual Alumina Capacity, by Country 8
Table 19.—Alumina: World Production, by Country 8
Table 20.—Salient Aluminum Statistics 9
Table 21.—Primary Annual Aluminum Production Capacity in the United States, by Company 10
Table 22.—U.S. Consumption of and Recovery From Purchased New and Old Aluminum Scrap, by Class 11
Table 23.—U.S. Stocks, Receipts, and Consumption of Purchased New and Old Aluminum Scrap and Sweated Pig in 1989 12

COVER PHOTO:
The entire spectrum of the aluminum industry: bauxite, alumina, and aluminum. (Photo is courtesy of Aluminum Co. of America, Pittsburgh, PA).

Table 24.—Production and Shipments of Secondary Aluminum Alloys by Independent Smelters in the United States 13
Table 25.—U.S. Apparent Aluminum Supply and Consumption 14
Table 26.—Distribution of End-Use Shipments of Aluminum Products in the United States, by Industry 15
Table 27.—U.S. Net Shipments of Aluminum Wrought and Cast Products, by Producers 15
Table 28.—Distribution of Wrought Products in the United States 15
Table 29.—Tariff Codes for U.S. Exports of Aluminum 15
Table 30.—U.S. Exports of Aluminum, by Class 16
Table 31.—U.S. Exports of Aluminum, by Country 17
Table 32.—Tariff Codes for U.S. Imports of Aluminum 18
Table 33.—U.S. Imports for Consumption of Aluminum, by Class 19
Table 34.—U.S. Imports for Consumption of Aluminum, by Country 20
Table 35.—Aluminum: World Annual Primary Production Capacity, by Country 21
Table 36.—Aluminum, Primary: World Production, by Country 22
Table 37.—Typical Specifications for Grades of Bauxite 23
Table 38.—Cell-Grade Alumina Specifications, in Weight-Percent .. 23
Table 39.—Composition Limits and Uses of Some Aluminum Wrought and Casting Alloys 24
Table 40.—World Bauxite Resources, December 1989 25
Table 41.—Aluminum Production Potential and Costs for Selected Countries 30

For comments or further information, please contact
The Branch of Nonferrous Metals
The Division of Mineral Commodities
Bureau of Mines
2401 E St., NW, MS 5208
Washington, DC 20241-0001
Telephone: (202) 634-1080
Fax: (202) 634-6628

BAUXITE, ALUMINA, AND ALUMINUM

By Errol D. Sehnke and Patricia A. Plunkert

Mr. Sehnke is a physical scientist with 16 years industry and Bureau of Mines experience. Domestic survey data for bauxite and alumina were prepared by Shonta E. Osborne, mineral data assistant, Nonferrous Metals Data Section; and international data tables were prepared by Harold D. Willis and Virginia A. Woodson, International Data Section.

Ms. Plunkert, a physical scientist with 21 years Bureau of Mines experience, has been the commodity specialist for aluminum since 1987. Domestic survey data for aluminum were prepared by Regina R. Coleman, mineral data assistant, Nonferrous Metals Data Section; and international data tables were prepared by Audrey D. Wilkes, International Data Section.

BAUXITE AND ALUMINA

World production of bauxite and alumina rose during 1989 to record high levels in response to a strong but moderating demand for primary aluminum metal. Mine production of bauxite was reported from 26 countries. Domestic consumption of bauxite increased significantly, with the majority of the increase driven by metal market requirements for primary aluminum. Within the specialty materials area, consumption of abrasive grade bauxite was comparable with 1988 usage, but bauxite consumption by the chemical and refractory industries declined in 1989. Demand for alumina was strong but weakened at the end of the year, easing the tight supply situation that had developed in the past several years. U.S. production and shipments of cell-grade alumina increased, while specialty alumina production and shipments declined sharply during the year. Alumina was produced in 25 countries.

Legislation and Government Programs

On September 1, 1989, the Environmental Protection Agency (EPA) presented its final rule on the list of specific solid wastes from ore and mineral processing that would remain within the Bevill exclusion amendment to the Resource Conservation and Recovery Act (RCRA) as special wastes. Red and brown muds generated in the bauxite refining process were among five processing waste streams that were found to satisfy all of the special waste criteria for exclusion from regulation as hazardous wastes under subtitle C of RCRA.[1]

The EPA proposed to delete nonfiberous aluminum oxide from the list of toxic chemicals contained in the Superfund Amendments and Reauthorization Act passed by Congress in October 1986; final removal of the toxic chemical designation was expected to occur in early 1990.

The National Defense Stockpile (NDS) goals for bauxite remained unchanged at 21.3 million metric tons of Jamaica-type and 6.2 million tons of Suriname-type metallurgical grade bauxite. Goals for calcined refractory grade and abrasive grade bauxite were 1.4 million and 1 million tons, respectively. The Defense Logistics Agency, manager of the NDS, listed an inventory of 12.7 million tons of Jamaica-type and 5.4 million tons of Suriname-type metallurgical grade bauxite. The NDS contained 279,000 tons of calcined refractory grade bauxite and no stocks of abrasive grade bauxite at the close of 1989.

Production

Bauxite was produced from surface mining operations in Alabama, Arkansas, and Georgia. At Bauxite, AR, the Aluminum Co. of America (Alcoa) mined bauxite for use in the manufacture of proppants for the petroleum industry and processed crude ore at the company's local alumina plant to produce specialty aluminum oxides and hydroxides. Alcoa announced that its mining and refining operations in Arkansas were scheduled for permanent closure in 1990, but that the alumina chemical products production would continue at this location using alumina feedstocks from other company facilities. Harbison-Walker Refractories Div. of Dresser Industries Inc. shipped bauxite from mines in Alabama to its local calcining plant and to Carbo Ceramic Co.'s proppant plant in Eufaula, AL. Mullite Co. of America (Mulcoa) mined bauxite in Alabama and Georgia, which was shipped to Mulcoa's processing plant in Andersonville, GA, for the production of refractory materials.

Martin Marietta Corp.'s 635,000-ton-per-year alumina plant on the Is-

TABLE 1

SALIENT BAUXITE STATISTICS

(Thousand metric tons and thousand dollars)

	1985	1986	1987	1988	1989
United States:					
Production: Crude ore (dry equivalent)	674	510	576	588	W
Value[e]	12,855	10,361	10,916	10,566	W
Exports (as shipped)	56	69	201	63	44
Imports for consumption[1]	7,158	6,456	9,156	9,944	10,666
Consumption (dry equivalent)	8,206	6,901	9,548	10,074	11,805
World: Production	84,189	[r]87,751	91,724	[p]97,946	[e]105,029

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Excludes calcined bauxite. Includes bauxite imported to the U.S. Virgin Islands.

land of St. Croix in the U.S. Virgin Islands was purchased in April by Clarendon Ltd., an aluminum trading group based in Switzerland. Damage caused by Hurricane Hugo hampered efforts to restart the facility, which had been idle since 1985. The new owners announced that the refinery, renamed Virgin Islands Alumina Inc. (Vialco), should be operational in the first quarter of 1990.

Reynolds Metals Co. announced plans to spend approximately $50 million over the next 2 years to increase the efficiency of its 1.7-million-ton-per-year alumina plant near Corpus Christi, TX.

Consumption and Uses

A continued strong demand for cell-grade alumina propelled consumption of crude and dried metallurgical grade bauxite to a level well above that of 1988. Most of this increase was supplied from imports. Consumption of bauxite by the abrasive industries was essentially unchanged during 1989, while consumption by the chemical and refractory industries decreased for the year. About 90% of the bauxite consumed in the United States was refined to alumina, and an estimated average of 2.31 tons of dried bauxite was required to produce 1 ton of calcined alumina. Twenty-two primary aluminum smelters reported consumption of 8 million tons of calcined alumina in 1989. An estimated 97% of the alumina shipped by U.S. refineries went to domestic primary smelters for metal production. Consumption in various forms by the abrasives, chemicals, refractories, and other industries accounted for the balance of the alumina usage.

Prices

Contract terms for the purchase of metallurgical grade bauxite and cell-grade alumina in world markets are not normally made public, and, consequently, prices for these commodities are not published by trade journals. Price quotes are generally limited to certain specialty forms of bauxite and alumina for nonmetallurgical uses.

In 1989, the Bureau of Mines estimated the average value of domestic crude bauxite shipments, f.o.b. mine or plant, to be $16 per ton. The average value of calcined domestic bauxite was estimated to be $132 per ton. Base

TABLE 2

MINE PRODUCTION OF BAUXITE AND SHIPMENTS FROM MINES AND PROCESSING PLANTS TO CONSUMERS IN THE UNITED STATES

(Thousand metric tons and thousand dollars)

Year	Mine production			Shipments from mines and processing plants to consumers[1]		
	Crude	Dry equivalent	Value[2]	As shipped	Dry equivalent	Value[2]
1987	689	576	10,916	756	680	22,173
1988	714	588	10,566	770	688	24,703
1989	W	W	W	W	W	W

W Withheld to avoid disclosing company proprietary data.
[1] May exclude some bauxite mixed in clay products.
[2] Computed from values assigned by producers and from estimates of the Bureau of Mines.

TABLE 3

PERCENT OF DOMESTIC BAUXITE SHIPMENTS, BY SILICA CONTENT

SiO_2 (percent)	1985	1986	1987	1988	1989
Less than 8	74	77	70	71	88
From 8 to 15	14	—	7	5	7
More than 15	12	23	23	24	5

TABLE 4

PRODUCTION AND SHIPMENTS OF ALUMINA IN THE UNITED STATES

(Thousand metric tons)

Year	Calcined alumina	Other alumina[2]	Total[1]	
			As produced or shipped[3]	Calcined equivalent
Production:[e]				
1985	2,860	860	3,725	3,465
1986	2,570	750	3,320	3,105
1987	3,555	830	4,385	4,150
1988	3,885	1,110	4,995	4,575
1989	4,580	285	4,860	4,670
Shipments:[e]				
1985	2,890	760	3,650	3,425
1986	2,590	740	3,330	3,120
1987	3,530	845	4,375	4,135
1988	4,645	1,115	5,760	5,340
1989	4,665	605	5,270	4,815

[e] Estimated.
[1] Data may not add to totals shown because of independent rounding.
[2] Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.
[3] Includes only the end product if one type of alumina was produced and used to make another type of alumina.

TABLE 5

CAPACITIES OF DOMESTIC ALUMINA PLANTS,[1] DECEMBER 31

(Thousand metric tons)

Company and plant	1987	1988	1989
Aluminum Co. of America:			
Bauxite, AR	340	340	340
Point Comfort, TX	1,735	1,735	1,735
Total	2,075	2,075	2,075
Kaiser Aluminum & Chemical Corp.: Gramercy, LA	795	795	795
Ormet Corp.: Burnside, LA	—	545	545
Reynolds Metals Co.: Corpus Christi, TX	1,700	1,700	1,700
Grand total	4,570	5,115	5,115

[1] Capacity may vary depending on the bauxite used.

prices quoted by Industrial Minerals magazine and independent sources for imported calcined refractory grade bauxite were as follows: Chinese, typical 85% alumina (Al_2O_3), f.o.b. barge, Burnside, LA, $90 to $130 per ton; and Guyanese, f.o.b. rail car, Baltimore, MD, or f.o.b. barge, Gulf Coast, $164.28 per ton. Abrasive grade bauxite, minimum 86% Al_2O_3, c.i.f. main European port, was priced at $95 to $108 per ton. Base prices were subject to adjustment for various grain-size specifications, size of order, and fuel cost factors.

The average value of domestic calcined alumina shipments was estimated to be $310 per ton. Trade data released by the Bureau of the Census indicated the average value of imported calcined alumina was $280 per ton, f.a.s. port of shipment, and $295 per ton, c.i.f. U.S. ports.

Foreign Trade

Dried bauxite exports totaled 18,900 tons in 1989, a continuation of the sharp downward trend recorded in 1988. Canada received 15,700 tons; Mexico, 1,300 tons; and Algeria, 1,000 tons. U.S. exports of calcined refractory grade bauxite totaled 12,000 tons for 1989. Mexico received 8,900 tons

TABLE 6

U.S. CONSUMPTION OF BAUXITE, BY INDUSTRY

(Thousand metric tons, dry equivalent)

Industry	Domestic	Foreign	Total
1988:			
Alumina	[1] 506	[1] 8,738	8,970
Abrasive[2]	W	W	274
Chemical	W	W	236
Refractory	[3] 140	[3] 690	524
Other	W	W	70
Total	646	9,428	10,074
1989:			
Alumina	W	[1] 10,538	10,782
Abrasive[2]	W	W	275
Chemical	W	W	223
Refractory	W	[3] 727	402
Other	W	W	123
Total	540	11,265	11,805

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Includes "Abrasive."
[2] Includes consumption by Canadian abrasive industry.
[3] Includes "Chemical" and "Other."

TABLE 7

U.S. CONSUMPTION OF CRUDE AND PROCESSED BAUXITE

(Thousand metric tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total
1988:			
Crude and dried	W	W	9,259
Calcined and activated	W	W	815
Total	646	9,428	10,074
1989:			
Crude and dried	W	W	11,104
Calcined and activated	W	W	701
Total	540	11,265	11,805

W Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 8

PRODUCTION AND SHIPMENTS OF SELECTED ALUMINUM SALTS IN THE UNITED STATES IN 1988

Item	Number of producing plants	Production (thousand metric tons)	Total shipments, including interplant transfers	
			Quantity (thousand metric tons)	Value (thousands)
Aluminum sulfate:				
Commercial and municipal (17% Al_2O_3)	79	1,118	1,057	$123,007
Iron-free (17% Al_2O_3)	24	125	123	15,547
Aluminum chloride:				
Liquid and crystal	3	W	W	W
Anhydrous (100% $AlCl_3$)	4	W	W	W
Aluminum fluoride, technical	3	W	W	W
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	7	587	662	159,953
Aluminates	15	61	64	27,603
Other aluminum compounds[1]	NA	NA	NA	90,337

NA Not available. W Withheld to avoid disclosing company proprietary data.
[1] Includes light aluminum hydroxide, cryolite, etc.

Source: Data are based on Bureau of the Census 1988 Current Industrial Reports, Series MA-28A, "Inorganic Chemicals."

TABLE 9

STOCKS OF BAUXITE IN THE UNITED STATES,[1] DECEMBER 31

(Thousand metric tons, dry equivalent)

Sector	1988[r]	1989
Producers, processors, and consumers	3,021	2,891
Government	18,474	18,474
Total	21,495	21,365

[r]Revised.
[1]Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.

TABLE 10

STOCKS OF ALUMINA IN THE UNITED STATES,[1] DECEMBER 31

(Thousand metric tons, calcined equivalent)

Sector	1988[r]	1989
Producers	[e]710	[e]601
Primary aluminum plants	1,252	1,346
Total	[e]1,962	[e]1,947

[e]Estimated. [r]Revised.
[1]Excludes consumers' stocks other than those at primary aluminum plants.

and Canada 1,900 tons. Exports of all other grades of calcined bauxite (chiefly abrasive grade) amounted to 12,900 tons for the year. Canada received 8,600 tons and Venezuela 4,200 tons. Specialty aluminum compounds exported included 940 tons of aluminum sulfate, 17,200 tons of aluminum oxide abrasives, and 34,300 tons of various fluoride-based compounds of aluminum, including synthetic cryolite and aluminum fluoride.

Imports for consumption of crude and dried bauxite increased from 1988 receipts, and the three traditional primary suppliers, Guinea, Jamaica, and Australia, in order of shipments, provided most of the total. Brazil's shipments to the United States increased sharply, and it greatly strengthened its fourth place ranking.

World Review

World production of bauxite and alumina continued the upward trends that began in the mid-1980's. Twenty-six countries mined bauxite in 1989, and the total world production of bauxite reached a record 105 million tons, an increase of 7% over 1988 produc-

TABLE 11

AVERAGE VALUE OF U.S. IMPORTS OF CRUDE AND DRIED BAUXITE[1]

(Per metric ton)

Country	1988		1989	
	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
To U.S. mainland:				
Australia	$14.75	$22.42	$15.94	$25.37
Brazil	25.55	33.72	31.22	40.59
Guinea	22.89	29.63	30.85	38.62
Guyana	30.53	42.84	30.15	42.06
Jamaica	29.25	33.70	26.23	30.82
Suriname	34.15	48.04	—	—
Weighted average	23.90	30.34	26.89	34.44

[1]Computed from quantity and value data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

TABLE 12

MARKET QUOTATIONS ON ALUMINA AND ALUMINUM COMPOUNDS

(Per metric ton, in bags, carlots, freight equalized)

Compound	Dec. 30, 1988	Dec. 29, 1989
Alumina, calcined	$418.88	$418.88
Alumina, hydrated, bulk	209.44	278.88
Alumina, activated, granular, works	905.00	905.00
Aluminum sulfate, commercial, ground,(17% Al_2O_3)	239.20	253.53
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	369.27	358.25

Source: Chemical Marketing Reporter.

TABLE 13

U.S. EXPORTS OF ALUMINA,[1] BY COUNTRY

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1987		1988		1989	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	1	629	1	740	1	849
Belgium-Luxembourg[2]	2	2,543	3	2,955	5	5,292
Brazil	75	10,789	115	19,780	20	6,966
Canada	575	39,890	509	91,337	942	257,466
France	1	2,005	1	1,422	3	2,225
Germany, Federal Republic of	1	2,989	2	3,372	2	7,216
Ghana	270	38,942	183	27,854	125	22,579
Japan	24	8,162	20	7,491	23	19,842
Mexico	150	32,431	175	35,341	150	56,280
Netherlands	2	2,274	3	3,520	8	9,709
Sweden	(3)	106	(3)	323	27	5,634
United Kingdom	2	2,134	6	3,448	2	4,471
Venezuela	2	1,512	4	3,028	3	2,008
Other	22	[r]13,618	[r]15	[r]15,495	17	19,388
Total[4]	1,127	[r]208,026	1,036	216,107	1,328	419,924

[r]Revised.
[1]Includes exports of aluminum hydroxide (calcined equivalent) as follows: 1987—18,727 tons; 1988—15,656 tons; and 1989—33,316 tons.
[2]For 1987, Belgium and Luxembourg combined, data not available to separate; 1988 and 1989 data for Belgium only.
[3]Less than 1/2 unit.
[4]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census

tion. Australia, Guinea, Jamaica, and Brazil, in order of volume, accounted for 70% of the total bauxite mined during the year. The corresponding world output of alumina rose to nearly 39 million tons, also a new production record, and was 6% greater than the 1988 production level. Three countries, Australia, the U.S.S.R., and the United States, contributed nearly 50% of the total world production.

TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF BAUXITE, CRUDE AND DRIED,[1] BY COUNTRY

(Thousand metric tons)

Country	1987	1988	1989
Australia	1,167	1,612	1,535
Brazil	451	792	1,372
China	5	20	69
Dominican Republic[2]	70	33	—
Ghana	36	—	—
Guinea	4,256	4,526	3,390
Guyana	244	225	379
Indonesia	—	39	306
Jamaica[2]	2,799	2,654	3,330
Malaysia	23	12	59
Sierra Leone	—	29	167
Suriname	104	3	—
Other	—	—	58
Total[3]	9,156	9,944	10,666

[1] Includes bauxite imported to the U.S. Virgin Islands from foreign countries.
[2] Dry equivalent of shipments to the United States.
[3] Data may not add to totals shown because of independent rounding.

Note: Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands) as reported by the Bureau of the Census were as follows: 1987—9,827,818 tons; 1988—10,498,913 tons; and 1989—11,346,182 tons.

Source: Bureau of the Census and The Jamaican Bauxite Institute.

Capacity.—A slight increase in the annual rated capacity of plants producing alumina helped to alleviate the shortages of cell-grade alumina required for the production of primary aluminum that had developed in recent years.

Australia.—In 1989, the world's largest bauxite and alumina producing country achieved new production records for the seventh consecutive year.

The Comalco Ltd. mining operations at Weipa, Queensland, operated at full annual rated capacity during the year and produced about 9.7 million tons of bauxite. Comalco announced that, in addition to the main production based on standard metallurgical grade bauxite and about 250,000 tons a year of abrasive grade product, trial shipments of cement grade, chemical grade, and trihydrate bauxite were made to markets in the United States and Europe. The Queensland Alumina Ltd. alumina plant at Gladstone reported that it was expanding its capac-

TABLE 15

U.S. IMPORTS FOR CONSUMPTION OF CALCINED BAUXITE, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1988				1989			
	Refractory grade		Other grade		Refractory grade		Other grade	
	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]	Quantity	Value[1]
Australia	—	—	20	1,788	—	—	8	570
China	103	6,696	152	8,765	176	10,044	147	8,218
Guinea	—	—	—	—	—	—	114	3,036
Guyana	98	12,948	15	836	74	10,871	96	3,449
Malaysia	—	—	—	—	—	—	113	1,073
Suriname	5	175	—	—	—	—	—	—
Other	(2)	15	(2)	7	5	292	26	1,233
Total[3]	206	19,834	188	11,396	254	21,207	505	17,579

[1] Value at foreign port of shipment as reported to U.S. Customs Service.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF ALUMINA,[1] BY COUNTRY

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1987		1988		1989	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	3,361	431,041	3,532	562,479	3,603	915,113
Brazil	25	4,977	65	15,574	44	21,465
Canada	59	25,078	91	39,241	154	69,711
France	7	13,825	6	14,740	5	13,369
Germany, Federal Republic of	14	20,922	20	27,328	20	30,576
Guinea	13	2,484	—	—	—	—
India	—	—	79	1,761	36	8,916
Israel	25	3,612	—	—	—	—
Italy	20	3,037	(3)	783	(3)	386
Jamaica	90	13,107	201	47,890	217	92,144
Japan	6	6,688	7	8,503	8	13,109
Suriname	324	40,568	417	77,124	209	52,124
Venezuela	111	13,936	207	34,286	1	136
Other	13	2,586	8	22,142	15	11,075
Total[4]	4,068	581,864	4,634	851,851	4,311	1,228,123

[1] Includes imports of aluminum hydroxide.
[2] Value at foreign port of shipment as reported to U.S. Customs Service.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

ity from 3 million to 3.3 million tons per year of alumina by "sweetening" the refining process with trihydrate bauxite from Comalco's Weipa operations, the sole source of the refinery's bauxite feed.

The Gove bauxite-alumina project in the Northern Territories, managed by Nabalco Pty. Ltd., produced 6 million tons of bauxite and 1.45 million tons of alumina in 1989. Participants in this project released plans to increase the alumina plant capacity at Gove by 150,000 tons per year.

Alcoa of Australia Ltd. announced that it planned to proceed with the second stage of its Wagerup alumina plant expansion in Western Australia. The 630,000-ton expansion would double the capacity at the refinery and was part of a two-stage program to increase the total alumina output at Alcoa's three Australian refineries (Wagerup, Kwinana, and Pinjarra) from 5.5 million to 6.1 million tons per year.

The U.S. International Trade Commission determined on March 21, 1989, under Section 735(b) of the Tariff Act of 1930, that U.S. industry was not materially injured or threatened with material injury by imports of calcined proppants from Australia that were found to have been sold in the United States at less than fair market value.[2]

Brazil.—Mineração Rio do Norte S.A. (MRN), the world's third-largest bauxite producer and exporter, reported it had begun an expansion program at its Trombetas mining operation in Pará State that would increase mine capacity from 6.5 million to 8.5 million tons per year. MRN indicated that the main focus of this program was the transfer of its existing ore-crushing and -washing facilities to sites within the proximity of active mine workings, plus the construction of a new system for tailings thickening and disposal.

The state-owned mining company Cia. Vale do Rio Doce announced preparation of a feasibility study for a new bauxite mining operation at Jabuti in the Paragominas region of Pará State.

Mineração Santa Lucrecia S.A. (MSL) indicated that the new refractory bauxite beneficiation plant it was installing at its Caracuru mine in the Almeirim district of Pará State would have a capacity of 200,000 tons per year of green bauxite product. MSL stated that construction had also commenced on a 60,000-ton-per-year production capacity rotary calciner near the Jari River port of Munguba, and the plant was expected to be operational in early 1990.

Companhia Brasileira de Alumínio (CBA) announced that the new alumina and aluminum plants it was installing near its existing complex at Sorocaba, in São Paulo State, would utilize bauxite supplied by the company's 850,000-ton-per-year Pocos de Caldas mines in Minas Gerais. CBA indicated that it planned to rely on the newly discovered bauxite reserves near Cataguazes in Rio de Janeiro State to supply the Sorocaba operations following the depletion of the ore reserves at Poços de Caldas.

Canada.—Alcan Aluminium Ltd. announced that a solar drying method of red-mud disposal was introduced at its Vaudreuil alumina plant in Quebec to provide a more environmentally compatible method for handling these mineral processing wastes.

Germany, Federal Republic of.—In mid-1989, Vereinigte Aluminium-Werke AG (VAW) announced its withdrawal from tabular alumina production in the Federal Republic of Germany.

Guinea.—Compagnie des Bauxites de Guinée (CBG) produced about 11.2 million tons of the total bauxite mined. CBG reportedly achieved this production despite infrastructure problems due to working beyond normal rated capacity.

Hydro Aluminium A/S of Norway announced that it bought a 20% share in Frialco, the 51% owner of the bauxite and alumina company, Frigua. The new shareholder structure for Frialco was reported as follows: Pechiney 30%, Noranda 30%, Alcan 20%, and Hydro 20%.

A modernization project, financed by the European Community, was reportedly started by Frigua at its Kimbo bauxite-alumina complex.

Guyana.—The decline in bauxite production recorded for 1989 was partially due to a 7-week strike by bauxite workers at the state-owned Guyana Mining Enterprise Ltd. (Guymine).

The Government of Guyana and Reynolds International Inc., a wholly owned subsidiary of Reynolds Metals, reported the signing of an agreement to mine and market bauxite from deposits at Aroaima in the Berbice region of Guyana.

Norway's Hydro Aluminium and Kaiser Aluminum & Chemical Corp. of the United States reportedly participated in a feasibility study conducted for the state-owned Bauxite Industry Development Corp. to determine what would be required to reopen the Linden alumina plant that had been closed since 1982. It was reported that an estimated $106 million would be required to restart the idled refinery.

The U.S. firm Green Mining Inc. announced that it began work under an 18-month contract with the Government to remove 1.3 million cubic meters of overburden and mine approximately 800,000 tons of metallurgical grade bauxite at Linden. Green Mining reported that it had delivered its first shipment of bauxite to Guymine in mid-September.

At yearend, Alcan Aluminium announced the signing of an agreement to study the feasibility of renovating Guyana's bauxite production and marketing operations at Linden.

India.—Bharat Aluminium Company announced the closure of its bauxite mining project in the Gandhamardhan Hills, Orissa State, because of strong environmental opposition by the local population. Heightened environmental awareness prompted the Indian State-owned National Aluminium Co. to publicize the environmental preservation and restoration programs developed for their bauxite mining areas.

Italy.—Clarendon Ltd. reportedly bought an 18% interest in Eurallumina SpA the owner-operator of the 720,000-ton-per-year alumina plant at Porto Veseme, Sardinia. This reduced the share of ownership held by the State-owned Allumina SpA from 62.5% to 52.1% and that of the Australian-owned Comalco from 37.5% to 29.9%.

Jamaica.—The Alumina Partners of Jamaica (Alpart) alumina plant at Nain, owned by Kaiser Aluminum (65%) and Hydro Aluminium (35%), restarted operations in April after being closed since 1985.

Plans to increase the capacity of the

Jamaica alumina plant in central Jamaica, jointly owned by the Government and Alcoa, were reportedly delayed by technical problems following a strike and 2-week shutdown in July and August.

Suriname.—The Suriname Aluminum Co. mining operations at Moengo reportedly experienced a brief shutdown in October due to civil strife and ethnic violence associated with the continuing political conflict and insurgent rebel action that had troubled the country in recent years.

Sweden.—On March 27, 1989, the U.S. International Trade Commission determined there was no reasonable indication that U.S. industry was materially injured or threatened by imports of dry aluminum sulfate from Sweden that had been allegedly sold within the United States at less than fair value.[3]

Venezuela.—The U.S. Department of Commerce reported on October 18, 1989, that aluminum sulfate imports from Venezuela had been subsidized and sold in the United States at less than fair market value.[4] In December, the U.S. International Trade Administration determined that U.S. industry was materially injured by the imports of aluminum sulfate from Venezuela and these imports were liable for assessment of antidumping and countervailing duties.[5]

TABLE 17

BAUXITE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Australia	31,839	32,384	34,102	36,192	[2]38,583
Brazil	5,846	6,544	6,567	7,728	8,500
China[e]	1,650	1,650	2,400	3,500	4,000
Dominican Republic[3]	—	—	211	106	[2]164
France	1,530	1,379	1,271	878	800
Germany, Federal Republic of	([4])	([4])	—	—	—
Ghana	170	226	230	300	[2]375
Greece	2,453	2,230	2,472	[r]2,400	2,400
Guinea[e 5]	11,790	13,300	13,500	15,600	[2]16,523
Guyana[3]	[r]1,675	2,074	2,785	1,774	[2]1,281
Hungary	2,815	3,022	3,101	2,593	2,700
India	2,281	2,322	2,736	3,961	[2]4,768
Indonesia	830	650	635	513	[2]862
Italy	—	—	17	17	17
Jamaica[3 6]	6,239	6,944	7,660	7,408	[2]9,395
Malaysia	492	566	482	361	350
Mozambique	5	4	5	7	[2]6
Pakistan	2	3	3	2	[2]2
Romania[e]	600	600	600	600	[2]313
Sierra Leone	1,185	1,246	1,390	1,379	[2]1,500
Spain	2	3	1	2	3
Suriname	3,738	3,731	2,522	3,434	[2]3,530
Turkey	214	280	247	269	345
U.S.S.R.[e 7]	4,600	4,600	4,600	4,600	4,600
United States[3]	674	510	576	588	W
Venezuela	—	—	217	700	[2]760
Yugoslavia	3,538	3,459	3,394	3,034	[2]3,252
Zimbabwe	21	24	—	—	—
Total	84,189	[r]87,751	91,724	97,946	105,029

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1] Table includes data available through June 13, 1990.

[2] Reported figure.

[3] Dry bauxite equivalent of crude ore.

[4] Less than 1/2 unit.

[5] Dry bauxite equivalent of ore processed by drying plant.

[6] Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

[7] In addition to the bauxite reported in the body of the table, the U.S.S.R. produces nepheline syenite concentrates and alunite ore as sources of aluminum. Nepheline syenite concentrate production was as follows, in thousand metric tons: 1985—1,615; 1986—1,638; 1987—1,660; 1988—1,640; and 1989—1,600 (estimated). Estimated alunite ore production was as follows, in thousand metric tons: 1985—615; 1986—620; 1987—625; 1988—625; and 1989—600. Nepheline syenite concentrate grades 25% to 30% alumina, and alunite ore grades 16% to 18% alumina; these commodities may be converted to their bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton of bauxite and 1 ton of alunite equals 0.34 ton of bauxite.

Current Research

Exploratory research by the Bureau of Mines on high-temperature structural materials for new and emerging technologies demonstrated that hard, dense composite materials can be produced from metallic nitrides such as titanium or zirconium when combined with alumina (Al_2O_3) and aluminum nitride (AlN). Of these nitrides, titanium nitride (TiN) has shown the best results for meeting the high-performance demands placed upon this new class of advanced materials, and investigations have been conducted to characterize the physical properties of various combinations of ceramic particulate composites made from the system TiN-Al_2O_3-AlN.[6]

The Ames Research Center of the National Aeronautics and Space Administration reported the development of a rigid, fiberous refractory composite material called "alumina-enhanced thermal barrier" (AETB) that extends the high-temperature capability of insulating materials.[7] This improved fiberous ceramic tile material had a composition of 14% aluminoborosilicate fibers, 66% silica fibers, and 20% alumina fibers. Although it was intended primarily for use in the heat shield of the Space Shuttle orbiter, the new material had obvious potential for industrial usage in kilns, furnaces, heat engines, and other applications for which lightweight and high operating temperature are major requisites.

An improved method for the removal of iron from Bayer process solutions was developed for mixed gibbsitic-boehmitic or boehmitic bauxites.[8] The removal of the iron oxide was achieved by passing the pregnant alumina plant liquors through a bed of activated sand

(washed and heated coarse red mud) that had a high iron oxide content, which promoted precipitation of iron from the solution.

Outlook

Known world bauxite reserves are sufficient to meet cumulative world demand well into the 21st century. Considering the high probability of discovering additional bauxite deposits and assuming reasonable energy costs, the added possibility of using lower grade bauxite deposits and other alternative sources of alumina, world resources of aluminum are adequate to meet demand for the foreseeable future.

As the costs of imported bauxite and alumina increase, alternate domestic sources of alumina may appear to become economically more attractive. On the other hand, high fuel prices tend to make nonbauxitic materials less competitive because the processes for treating alternate materials require considerably more energy than Bayer-processed bauxite. It therefore appears evident that nonbauxitic sources of aluminum would become viable only within the context of a prolonged national emergency or international embargo extending over a period of several years.

In the future, the structure of the aluminum industry was expected to see a continued shift of alumina production facilities from the aluminum-producing industrial countries with high energy costs, in North America and Europe, to the bauxite-producing countries of the world. Imports of primary aluminum metal from countries with low electrical energy costs and secondary production from recycled aluminum was likely to be used in ever-increasing proportions to meet the domestic demand for aluminum.

TABLE 18

WORLD ANNUAL ALUMINA CAPACITY, BY COUNTRY

(Thousand metric tons)

Country	1987	1988	1989
Australia	9,750	10,000	10,850
Brazil	1,150	1,150	1,555
Canada	1,225	1,225	1,140
China	850	1,300	1,500
Czechoslovakia	100	100	100
France	1,040	1,040	700
German Democratic Republic	65	60	60
Germany, Federal Republic of	1,745	1,745	1,380
Greece	500	500	600
Guinea	700	700	700
Guyana	355	355	300
Hungary	920	920	920
India	675	1,000	1,580
Ireland	800	800	900
Italy	920	720	720
Jamaica	2,825	3,100	2,950
Japan	975	550	500
Romania	540	540	540
Spain	800	800	1,000
Suriname	1,350	1,350	1,400
Turkey	200	200	200
U.S.S.R.	4,600	4,600	4,600
United Kingdom	120	120	120
United States	4,570	5,115	5,115
Venezuela	1,000	1,300	1,300
Yugoslavia	1,635	1,635	1,570
Total	39,410	40,925	42,300

TABLE 19

ALUMINA: WORLD PRODUCTION,[1] BY COUNTRY[2]

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Australia	8,792	9,423	10,109	10,518	[3]10,800
Brazil	1,096	1,258	1,326	[e]1,300	1,600
Canada	1,019	1,015	953	993	1,400
China[e]	825	825	1,200	[r]1,500	1,440
Czechoslovakia[e]	[r]75	[r]70	[r]75	[r]75	75
France	736	740	711	563	560
German Democratic Republic	47	46	51	64	60
Germany, Federal Republic of	1,657	1,560	1,313	1,145	1,200
Greece	380	470	518	514	521
Guinea	572	556	543	590	617
Hungary	798	856	858	873	870
India	587	586	650	1,188	[3]1,419
Ireland	555	686	784	843	865
Italy	555	618	700	708	700
Jamaica	1,622	1,586	1,572	1,522	[3]2,221
Japan	978	607	358	415	[3]466
Romania	548	555	584	[e]550	550
Spain[4]	725	748	801	[e]800	880
Suriname[4]	1,242	1,471	1,363	1,632	[3]1,567
Turkey	113	144	95	182	200
U.S.S.R.[e]	3,500	3,500	3,500	3,500	3,500
United Kingdom	110	[r]110	110	[e]110	110
United States[e]	3,465	3,105	4,150	[3]4,575	4,670
Venezuela	[e]1,085	1,269	1,381	[e]1,350	1,241
Yugoslavia	1,138	1,117	1,113	1,051	1,168
Total	[r]32,220	[r]32,921	34,818	36,561	38,700

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Figures represent calcined alumina or the total of calcined alumina plus the calcined equivalent of hydrate, when available; exceptions, if known, are noted.

[2] Table includes data available through June 13, 1990.

[3] Reported figure.

[4] Hydrate.

ALUMINUM

Most primary aluminum smelters operated close to and, in some cases, above rated capacities during the year. Exports of aluminum in 1989 increased significantly for the second successive

year to a level that was more than twice that of 1986. A record 49.4 billion used beverage cans (UBC) were recycled in 1989, equivalent to more than 60% of the aluminum can shipments for the year. Prices decreased during the year as world supply and demand came into a more balanced position. World production of primary aluminum approached a record 18 million tons for the year.

Legislation and Government Programs

The U.S. Department of Transportation issued a notice of proposed rulemaking to regulate materials that are transported at elevated temperatures. The proposed changes to the Hazardous Materials Regulations (49 CFR 171–179) would communicate the hazards of these elevated temperature materials by means of marking, shipping papers, and placarding, and would prescribe package requirements. Molten aluminum was one of the materials that would be covered by these proposed changes.[9]

The Office of the U.S. Trade Representative published lists of materials that were under consideration for negotiations with the Canadian Government for accelerated tariff elimination under the United States-Canada Free-Trade Agreement Implementation Act of 1988. These lists included some articles of aluminum for which acceleration of tariff elimination had been requested in petitions submitted either to the Government of the United States or to the Government of Canada.[10]

Production

Primary.—Domestic primary aluminum production was the highest annual production level since 1984. Most smelters operated at or above their rated capacity levels during the year.

In September, a power outage, caused by Hurricane Hugo, damaged the Alumax Inc. 181,000-ton-per-year primary aluminum smelter in Mount Holly, SC. The outage froze metal in the smelter potlines, but company officials reported that structural damage to the plant was not extensive. The company estimated that it would be 20 weeks before full production could be resumed at the plant. However, by the end of the year, a full 10 weeks ahead of schedule, the company announced that repairs had been completed and the plant was back in full production.

Ravenswood Aluminum Corp. announced plans to restart a fourth potline at its smelter in West Virginia, raising the rated capacity of the plant to 166,000 tons per year. This potline had been shut down since April 1981.

Alumax and the United Steelworkers of America (USWA) completed early contract negotiations covering workers at the Frederick, MD, and Ferndale, WA, smelters. In March, a new contract, scheduled to expire on October 1, 1992, was signed by workers at the Frederick, MD, smelter, replacing the previous contract, which was set to expire on October 24, 1990. In November, workers at the Ferndale, WA, plant ratified a new 3-year contract that was scheduled to expire on September 30, 1993. The new Ferndale smelter contract replaced the previous contract that was scheduled to expire at the end of September 1990.

In April, Alcan Aluminum Corp. and the Aluminum, Brick, and Glass Workers International Union (ABGWIU) announced the ratification and signing of a new labor contract covering workers at the Sebree, KY, smelter. This contract took effect immediately and replaced the previous contract that was not scheduled to expire until October 28. The new contract reportedly included an initial pay increase of 4.25%, plus increases of 3.5% in 1990, and 3% in 1991. Additional cash bonuses were also reported to be included in this new contract that was scheduled to expire on October 28, 1992.

Workers at Noranda Aluminum Inc.'s New Madrid, MO, smelter walked off their jobs on September 1, after the previous labor contract expired. The company reported that production levels at the plant would be maintained by salaried personnel. While negotiations continued between the USWA and management, workers returned to their jobs in December without ratifying a new contract.

Alcan Aluminum announced the purchase of Jarl Extrusions Inc., a maker of custom aluminum extrusions. Jarl reportedly operated five presses and a remelt, billet casting center at Elizabethton, TN, and two presses at its facility in Franklin, NH.

Alcan Rolled Products Co., a division of Alcan Aluminum, announced plans to upgrade its sheet rolling facility at Oswego, NY. The $175-million program was reported to include a modernization of the hot rolling mill, a

TABLE 20

SALIENT ALUMINUM STATISTICS

(Thousand metric tons and thousand dollars unless otherwise specified)

	1985	1986	1987	1988	1989
United States:					
Primary production	3,500	3,037	3,343	3,944	4,030
Value	6,249,614	5,422,993	5,328,300	9,572,066	7,801,086
Price: Average cents per pound					
U.S. producer list	81.0	[1]81.0	NA	NA	NA
U.S. market (spot)	48.8	55.9	72.3	110.1	87.8
Secondary recovery	1,762	1,773	1,986	2,122	2,054
Exports (crude and semicrude)	908	753	917	1,247	1,613
Imports for consumption (crude and semicrude)	1,420	1,967	1,850	1,620	1,470
Aluminum industry shipments[2]	6,382	6,545	6,813	r6,851	6,857
Consumption, apparent	5,174	5,143	5,469	r5,373	4,959
World: Production	15,398	r15,413	16,385	p17,608	e17,980

e Estimated. p Preliminary. r Revised. NA Not available.
[1] Based on 7 months in 1986.
[2] Shipped to domestic industry.

new melting and casting center, a pusher furnace-preheat facility, a high-speed precision slitting line, and a new roll grinder.

Alcan Aluminum also announced plans to construct an aluminum cable plant in Roseburg, OR. The plant reportedly would be completed by 1991 and would produce transmission and distribution conductor cable as well as aluminum building wire.

Kaiser Aluminum announced plans to build an aluminum forgings plant in Greenwood, SC. The company reported that it would enlarge an existing building on the site and would produce aluminum forgings primarily for the automotive market. Kaiser Aluminum expected production to begin by the end of the year.

Reynolds Metals reported the purchase of Conductor Products Inc., a cable plant in Marshall, TX. The plant manufactured overhead cable and insulated underground cable products.

Reynolds Metals also announced plans for a $30 million expansion and modernization of aluminum plate capacity at its McCook, IL, rolling mill. The company anticipated that the 2-year program, which targeted larger shares of the aircraft and aerospace markets, would increase aluminum plate capacity by 16% to 80 million pounds per year and increase machining capacity for wing skins by 50%.

Logan Aluminum Inc. announced a major two-stage expansion program for its aluminum can stock mill in Logan, KY, that would double the plant's capacity. The first phase of the program included a 90-inch high-speed cold mill, a coating line, a slitting line, two ingot preheat furnaces, and an ingot scalper. The second phase reportedly included another cold mill plus a fourth stand added to the hot mill. Logan Aluminum was jointly owned by Atlantic Richfield Co. (Arco) and Alcan Aluminum.

Columbia Aluminum Corp., which owns a primary aluminum smelter in Goldendale, WA, announced several acquisitions of fabrication facilities. Columbia Aluminum reported the purchase of an extrusion plant in Rockwall, TX, from Alumax; extrusion facilities in City of Industry, CA, and City of Commerce, CA, from Indal Ltd.; and an extrusion plant in Modesto, CA, from Pacific Aluminum Corp.

TABLE 21

PRIMARY ANNUAL ALUMINUM PRODUCTION CAPACITY IN THE UNITED STATES, BY COMPANY

Company	Yearend capacity (thousand metric tons)		1989 Ownership (percent)
	1988	1989	
Alcan Aluminum Corp.:			
Sebree, KY	163	163	Alcan Aluminium Ltd., 100%.
Alumax Inc.:			
Ferndale, WA (Intalco)	254	254	AMAX Inc., 75%; Mitsui & Co., 11%; Toyo Sash 7%; Yoshida Kogya K.K., 7%.
Frederick, MD (Eastalco)	160	160	Do.
Mount Holly, SC	181	181	AMAX, 73%; Clarendon Ltd., 27%.
Total	595	595	
Aluminum Co. of America:			
Alcoa, TN	200	200	Aluminum Co. of America, 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	270	270	Do.
Massena, NY	127	127	Do.
Rockdale, TX	310	310	Do.
Wenatchee, WA	205	205	Do.
Total	1,227	1,227	
Columbia Aluminum Corp.:			
Goldendale, WA	168	168	Columbia Aluminum Corp., 70%; employees, 30%.
Columbia Falls Aluminum Co.:			
Columbia Falls, MT	163	163	Montana Aluminum Investors Corp., 100%.
Kaiser Aluminum & Chemical Corp.:			
Mead, WA (Spokane)	200	200	MAXXAM Inc., 100%.
Tacoma, WA	73	73	Do.
Total	273	273	
National-Southwire Aluminum Co.:			
Hawesville, KY	172	172	National Steel Corp., 50%; Southwire Co., 50%.
Noranda Aluminum Inc.:			
New Madrid, MO	204	204	Noranda Mines Ltd., 100%.
Northwest Aluminum Corp.:[1]			
The Dalles, OR	82	82	Martin Marietta Corp., 87.2%; private interests, 12.8%.
Ormet Corp.:			
Hannibal, OH	245	245	Ohio River Associates Inc., 100%.
Ravenswood Aluminum Corp.:[2]			
Ravenswood, WV	110	166	Stanwich Partners Inc., 100%.
Reynolds Metals Co.:			
Longview, WA	204	204	Reynolds Metals Co., 100%.
Massena, NY	123	123	Do.
Troutdale, OR	121	121	Do.
Total	448	448	
Vanalco Inc.:			
Vancouver, WA	110	110	Vanalco Inc., 100%.
Grand total	3,960	4,016	

[1] Northwest Aluminum Corp. signed a lease-purchase agreement for The Dalles smelter with Martin Marietta Corp. in 1986.
[2] Purchased from MAXXAM Inc. in Dec. 1988.

VAW of America Inc. reported the purchase of Easco Corp.'s aluminum extrusion plant in Phoenix, AZ. The plant produced extrusions and pipes for the construction, building products, and consumer goods markets.

National Intergroup Inc. (NII), the parent company of National Aluminum Corp., announced the sale of its aluminum rolling and extrusions divisions. NII reported that Noranda had purchased a foil rolling mill in Newport, AR; a light-gauge foil mill in Salisbury, NC; and some laminating facilities in Ohio and Massachusetts. R. D. Werner announced the purchase of NII's custom extrusion plant in Anniston, AL.

Secondary.—According to a survey conducted by the Aluminum Association, the Institute of Scrap Recycling Industries, and the Can Manufacturers Institute, a record 49.4 billion aluminum UBC's were recycled in 1989, surpassing by almost 7 billion the number of UBC's recovered in 1988. The percentage of aluminum cans recycled in the United States increased from 54.6% of aluminum cans shipped in 1988 to 60.8% of can shipments in 1989.

Alcan Aluminum announced the opening of its new UBC recycling plant in Berea, KY. The company anticipated that the production from the 120,000-ton-per-year plant would be sent to the company's can sheet rolling mills in Henderson, KY, and Oswego, NY.

International Mill Service Inc. (IMS) reported that its UBC recycling plant in Hauser, ID, was operational. The plant reportedly had the capacity to convert at least 80 million pounds of UBC's and 40 million pounds of aluminum scrap per year into secondary metal, which could then be transported to Kaiser Aluminum's rolling facility in nearby Trentwood, WA. In addition, the IMS plant reportedly had the capability of processing 50 million pounds of aluminum dross annually.

Golden Aluminum Co. announced plans to construct a new continuous casting and roiling mill in San Antonio, TX. The plant reportedly would convert UBC's into 200 million pounds per year of beverage can body stock.

Secondary Aluminum Smelters Inc. announced the opening of a new 36-million-pound-per-year secondary smelter in Chattanooga, TN. Culp Industries Inc. announced the sale of its secondary smelter in Steele, AL, to Legett & Platt Inc., a producer of aluminum die-cast components for the home furnishing industry. In December, Apex International Alloys Co., a secondary aluminum smelter in Cleveland, OH, reported that the company had filed under Chapter 11 of the U.S. Bankruptcy Code.

American Recovery Technology Systems Inc. announced the completion of a closed-loop system for recycling secondary aluminum dross and salt cakes. Capacity of the system was reported to be 6 million pounds per month. The company said that the facility was designed to recover the salt flux and produce an exothermic flux for use by the steel industry and remelt secondary ingot producers.

Metal Mark Inc. announced plans to startup an aluminum dross processing plant late next year. The new company, to be located near Chicago Heights, IL, and to be named Columbia Aluminum Recycling Ltd., would reportedly become the fifth plant owned by Metal Mark.

Alcan Aluminium reported the development of a process for recycling aluminum dross that reportedly eliminated the use of salt fluxes employed in conventional treatment methods. The process reportedly used plasma-torch technology provided by Plasma Energy Corp. of Raleigh, NC. Alcan Aluminium announced that the company would begin industrial-scale testing of this process at its plant in Jonquiere, Quebec, in 1990.

Consumption

The container and packaging industry remained the largest domestic consumer of aluminum products. The Can Manufacturers Institute reported that about 83 billion aluminum beverage cans were shipped in 1989, representing almost 97% of the total metal beverage can shipments.

Reynolds Metals announced plans to begin commercial marketing of aluminum composite panels for use by the architectural industry. The panel combined a solid thermoplastic compound core with two sheets of aluminum. The panel reportedly was intended to serve a wide range of architectural applications, including designs where fire resistance was critical. The panel, called Reynobond, would be produced at the company's architectural products plant in Eastman, GA.

TABLE 22

U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP,[1] BY CLASS

(Metric tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
1988			
Secondary smelters	871,484	725,881	781,813
Primary producers	1,025,107	860,494	921,725
Fabricators	229,868	200,978	214,988
Foundries	71,499	59,297	63,755
Chemical producers	36,854	36,854	36,854
Total	2,234,812	1,883,504	2,019,135
Estimated full industry coverage	2,348,000	1,979,000	2,122,000
1989			
Secondary smelters	804,995	666,212	716,581
Primary producers	1,027,495	861,153	922,621
Fabricators	222,456	195,910	209,422
Foundries	83,024	67,581	72,842
Chemical producers	36,019	36,019	36,019
Total	2,173,989	1,826,875	1,957,485
Estimated full industry coverage	2,280,000	1,908,000	2,054,000

[1] Excludes recovery from other than aluminum-base scrap.

TABLE 23

U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP[1] AND SWEATED PIG IN 1989

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1[r]	Net receipts[2]	Consumption	Stocks, Dec. 31
Secondary smelters:				
New scrap:				
Solids	36,556	125,781	156,300	6,037
Borings and turnings	4,551	119,472	119,155	4,868
Dross and skimmings	2,396	20,808	21,574	1,630
Other[3]	5,347	84,836	87,865	2,318
Total	48,850	350,897	384,894	14,853
Old scrap:				
Castings, sheet, clippings	15,450	244,310	246,723	13,037
Aluminum-copper radiators	1,083	8,523	9,061	545
Aluminum cans	3,897	[4]107,015	[4]109,401	1,511
Other[5]	1,085	33,519	34,309	295
Total	21,515	393,367	399,494	15,388
Sweated pig	2,352	19,723	20,607	1,468
Total secondary smelters	72,717	763,987	804,995	31,709
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids	15,132	476,764	479,678	12,218
Borings and turnings	204	32,075	32,136	143
Dross and skimmings	1,012	10,036	9,389	1,659
Other[3]	3,595	158,,80	158,849	3,326
Total	19,943	677,455	680,052	17,346
Old scrap:				
Castings, sheet, clippings	1,296	120,767	120,911	1,152
Aluminum-copper radiators	39	1,411	1,396	54
Aluminum cans	18,182	561,127	542,157	37,152
Other[5]	1,474	—	1,474	—
Total	20,991	683,305	665,938	38,358
Sweated pig	1,154	22,601	23,004	751
Total primary producers, etc.	42,088	1,383,361	1,368,994	56,455
All scrap consumed:				
New scrap:				
Solids	51,688	602,545	635,978	18,255
Borings and turnings	4,755	151,547	151,291	5,011
Dross and skimmings	3,408	30,844	30,963	3,289
Other	8,942	243,416	246,714	5,644
Total new scrap	68,793	1,028,352	1,064,946	32,199
Old scrap:				
Castings, sheet, clippings	16,746	365,077	367,634	14,189
Aluminum-copper radiators	1,122	9,934	10,457	599
Aluminum cans	22,079	668,142	651,558	38,663
Other	2,559	33,519	35,783	295
Total old scrap	42,506	1,076,672	1,065,432	53,746
Sweated pig	3,506	42,324	43,611	2,219
Total of all scrap consumed	114,805	2,147,348	2,173,989	88,164

[r] Revised.

[1] Includes imported scrap. According to reporting companies, 6.04% of total receipts of aluminum-base scrap, or 129,795 metric tons, was received on toll arrangements.

[2] Includes inventory adjustment.

[3] Includes data on foil, can stock clippings, and other miscellaneous.

[4] Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.

[5] Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

TABLE 24

PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES

(Metric tons)

	1988		1989	
	Production	Net shipments[1]	Production	Net shipments[1]
Die-cast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	107,626	108,475	97,970	97,305
380 and variations	326,011	323,698	348,160	349,471
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	19,063	18,849	18,451	18,850
No. 12 and variations	W	W	W	W
No. 319 and variations	53,971	53,921	60,542	60,068
F-132 alloy and variations	6,945	6,781	6,826	6,763
Al-Mg alloys	224	222	49	68
Al-Zn alloys	2,390	2,296	1,913	2,170
Al-Si alloys (0.6% to 2.0% Cu)	6,933	6,737	9,710	9,837
Al-Cu alloys (1.5% Si, maximum)	1,189	1,176	350	449
Al-Si-Cu-Ni alloys	933	943	1,121	1,123
Other	3,672	3,626	1,209	1,237
Wrought alloys: Extrusion billets	108,052	108,052	126,482	124,714
Miscellaneous:				
Steel deoxidation	8,605	8,903	7,967	7,994
Pure (97.0% Al)	—	—	—	—
Aluminum-base hardeners	1,904	1,933	1,813	1,777
Other[2]	44,307	43,318	31,091	31,226
Total	691,825	688,930	713,654	713,052
Less consumption of materials other than scrap:				
Primary aluminum	46,939	—	55,731	—
Primary silicon	38,344	—	36,981	—
Other	5,405	—	3,536	—
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[3]	601,137	XX	617,406	XX

W Withheld to avoid disclosing company proprietary data; included with "Sand and permanent mold: Other." XX Not applicable.

[1] Includes inventory adjustment.

[2] Includes other die-cast alloys and other miscellaneous.

[3] No allowance made for melt-loss of primary aluminum and alloying ingredients.

Topy Corp., which has been manufacturing steel wheels since 1986, announced the completion of a new manufacturing facility for aluminum wheels. The new facility reportedly would have an annual production capacity of 800,000 units. Topy was the U.S. subsidiary of Topy Industries Ltd. of Japan.

A-Mold Corp., a newly established U.S. subsidiary of Ube Industries Ltd. of Japan, announced plans to construct an aluminum wheel manufacturing plant in Mason, OH. The company expected the plant to have an annual production capacity of 1 million units and to be completed in 1991.

Stocks

Inventories of aluminum ingot, mill products, and scrap at reduction and other processing plants, as reported by the U.S. Department of Commerce, decreased from the revised figure of about 1.88 million tons at yearend 1988 to about 1.82 million tons at yearend 1989.

Prices

The monthly average U.S. market price for primary aluminum ingot trended downward during the year as supply and demand came into a more balanced position. The London Metal Exchange (LME) and New York Commodity Exchange (COMEX) prices for aluminum futures followed the same general trend as the U.S. market prices. In January 1989, the LME changed the basis of its price quotes for aluminum ingot from standard-grade (99.5%-pure aluminum) to high-grade (99.7%-pure aluminum). This change more accurately reflects the material traded in the world market.

The following table summarizes various average monthly and annual aluminum prices during the year, in cents per pound:

	COMEX 1[1]	COMEX 2[1]	COMEX 3[1]	LME (cash)	U.S. market	U.S. transaction
1988: Annual average	111.13	106.57	88.13	[2]115.88	110.09	112.24
1989:						
January	106.91	107.67	94.23	108.75	107.73	108.89
February	96.32	97.40	89.61	99.02	99.58	100.95
March	92.15	93.05	84.06	94.06	95.78	97.53
April	93.70	93.70	85.90	96.42	96.38	97.61
May	97.15	96.27	88.76	102.48	97.80	99.18
June	88.74	86.34	81.82	86.83	87.66	89.30
July	82.55	80.78	77.85	79.65	80.40	81.45
August	81.28	80.78	79.07	81.57	81.37	82.34
September	78.23	78.18	76.75	77.92	78.30	79.05
October	79.23	78.64	78.43	82.56	79.76	80.30
November	76.16	75.70	75.85	78.75	75.81	76.25
December	72.85	73.30	73.98	74.08	73.56	74.22
Annual average	87.10	86.82	82.19	88.51	87.84	88.92

[1]COMEX delivery positions: 1-within 1 month; 2-within 3 months; and 3-within 12 months.
[2]Average for 11 months.

Source: Metals Week.

Purchase prices for aluminum scrap, as quoted by the American Metal Market (AMM), also decreased during the year. The purchase price for mixed low-copper-content aluminum clips, which began the year near 80 cents per pound, closed at a low 50-cent-per-pound level. Purchase prices for old sheet and cast aluminum, as well as clean, dry, aluminum turnings, decreased from the mid 60-cent-per-pound level to a mid 40-cent-per-pound level by the end of the year.

Prices for UBC's fluctuated during the year but also followed a general downward trend. Aluminum producers' buying prices for processed and delivered UBC's decreased from a range of 74 to 77 cents per pound in late January and early March to a price range of 50 to 53 cents per pound at the end of the year.

TABLE 25

U.S. APPARENT ALUMINUM SUPPLY AND CONSUMPTION

(Thousand metric tons)

	1985	1986	1987	1988[r]	1989
Primary production	3,500	3,037	3,343	3,944	4,030
Change in stocks:[1] Aluminum industry	+312	+108	+341	+11	+61
Imports	1,420	1,967	1,850	1,620	1,470
Secondary recovery:[2]					
New scrap	912	989	1,134	1,077	1,043
Old scrap	850	784	852	1,045	1,011
Total supply	6,994	6,885	7,520	7,697	7,615
Less total exports	908	753	917	1,247	1,613
Apparent aluminum supply available for domestic manufacturing	6,086	6,132	6,603	6,450	6,002
Apparent consumption[3]	5,174	5,143	5,469	5,373	4,959

[r]Revised.
[1]Positive figure indicates a decrease in stocks; negative figure indicates an increase in stocks.
[2]Metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage.
[3]Apparent aluminum supply available for domestic manufacturing less recovery from purchased new scrap (a measure of consumption in manufactured end products).

Secondary aluminum ingot prices, as quoted by AMM, also followed a downward trend. The yearend price ranges for selected secondary aluminum ingots were as follows: Alloy 380 (1% zinc content), 73 to 76 cents per pound; alloy 360 (0.6% copper content) and alloy 413 (0.6% copper content), 78 to 80 cents per pound; and alloy 319, 76 to 78 cents per pound.

Changes in aluminum metal prices from 1850–1988 and a brief analysis of the factors that influenced the changes were included in a Bureau of Mines report on nonferrous metal prices.[11]

Foreign Trade

For the third consecutive year, exports of all forms of aluminum from the United States increased substantially from those of the previous year. Total exports in 1989 were more than double those of 1986. Japan and Canada continued to be the major recipients of U.S. aluminum materials in 1989. Japan received three-fourths of the U.S. exports of crude metal and about one-half of the total exports of aluminum materials during the year. Exports of UBC's, which were included in the scrap category, totaled 17,354 tons in 1989, more than 4 times the quantity exported in 1988. Japan continued to be the principal destination of UBC's exported, accounting for more than one-half of the total in 1989.

Imports for consumption of aluminum decreased slightly compared with those of 1988. Canada remained the major shipping country to the United States, supplying three-fourths of the total U.S. imports in 1989.

U.S. tariff rates in effect in 1989 for selected aluminum products from countries with most-favored-nation status were as follows:

Item	HTS No.	Import duty
Unwrought metal (in coils)	7601.10.30	2.6% ad valorem.
	7601.20.30	Do.
Unwrought (other than Si-Al alloys)	7601.10.60	Free
	7601.20.90	Do.
Waste and scrap	7602.00.00	Free.

TABLE 26

DISTRIBUTION OF END-USE SHIPMENTS OF ALUMINUM PRODUCTS IN THE UNITED STATES, BY INDUSTRY

Industry	1987		1988		1989[p]	
	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total
Containers and packaging	2,052	27.8	2,036	26.7	2,104	26.6
Building and construction	1,441	19.5	1,316	17.2	1,296	16.4
Transportation	1,500	20.3	1,536	20.1	1,515	19.1
Electrical	620	8.4	671	8.8	679	8.6
Consumer durables	576	7.8	588	7.7	554	7.0
Machinery and equipment	401	5.4	435	5.7	443	5.6
Other markets	223	3.1	269	3.5	266	3.3
Total to domestic users	6,813	92.3	6,851	89.7	6,857	86.6
Exports	569	7.7	787	10.3	1,060	13.4
Grand total	7,382	100.0	7,638	100.0	7,917	100.0

[p] Preliminary.

Source: The Aluminum Association Inc.

TABLE 27

U.S. NET SHIPMENTS[1] OF ALUMINUM WROUGHT AND CAST PRODUCTS, BY PRODUCERS

(Metric tons)

	1988	1989[p]
Wrought products:		
Sheet, plate, foil	3,779,789	3,899,451
Rod, bar, pipe, tube, and shapes	1,336,657	1,280,301
Rod, wire, cable	334,118	338,888
Forgings (including impacts)	75,264	71,724
Powder, flake, paste	40,941	42,369
Total	5,566,769	5,632,733
Castings:		
Sand	115,351	NA
Permanent mold	201,334	NA
Die	699,897	NA
Other	37,934	NA
Total	1,054,516	1,095,508
Grand total	6,621,285	6,728,241

[p] Preliminary. NA Not available.

[1] Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

Source: U.S. Department of Commerce.

TABLE 28

DISTRIBUTION OF WROUGHT PRODUCTS IN THE UNITED STATES

(Percent)

	1988[r]	1989[p]
Sheet, plate, foil:		
Nonheat-treatable	58.4	58.2
Heat-treatable	3.9	3.9
Foil	7.3	7.1
Rod, bar, pipe, tube, shapes:		
Rod and bar (rolled and extruded)	1.7	1.2
Pipe and tube (extruded and drawn)	2.3	2.4
Extruded shapes	18.7	19.1
Rod, wire, cable:		
Rod and bar wire	.7	.5
Cable and insulated wire	5.1	5.5
Forgings (including impacts)	1.2	1.3
Powder, flake, paste	.7	.8
Total	100.0	100.0

[p] Preliminary. [r] Revised.

Source: U.S. Department of Commerce.

TABLE 29

TARIFF CODES FOR U.S. EXPORTS OF ALUMINUM

Material	1988	1989
	TSUS[1]	HTS[2]
Metals and alloys, crude	618.0300	7601.10.0000
	618.0630	7601.20.9030
	618.0670	7601.20.9045
	618.4500	7601.20.9500
Plates, sheets, bars, etc.:		
Plates, sheets, bars, strips, etc.	618.1520	7604.10.1000
	618.1540	7604.10.3010
	618.1700	7604.10.3050
	618.2810	7604.10.5030
	618.2830	7604.10.5060
	618.2850	7604.21.0000
	618.2870	7604.29.1000
	618.2890	7604.29.3010
		7604.29.3050
		7604.29.5030
		7604.29.5060
		7606.11.3030
		7606.11.3060
		7606.11.6000
		7606.12.3030
		7606.12.3070
		7606.12.6000
		7606.91.0010
		7606.91.0050
		7606.91.0070
		7606.91.0090
		7606.92.0010
		7606.92.0050
		7606.92.0070
		7606.92.0090
Castings and forgings	657.4320	7616.90.0060
	657.4342	7616.90.0070
Semifabricated forms, n.e.c.	618.4620	7608.10.0030
	618.4640	7608.10.0090
	618.4900	7608.20.0030
	688.3600	7608.20.0090
	688.3710	7609.00.0000
Scrap	618.1020	7601.20.9075
	618.1060	7602.00.0030
	618.1080	7602.00.0090
Foil and leaf	644.0720	7607.11.3000
	644.0740	7607.11.6000
		7607.11.9000
		7607.19.0000

See footnotes at end of table.

TABLE 29—Continued

TARIFF CODES FOR U.S. EXPORTS OF ALUMINUM

Material	1988	1989
	TSUS[1]	HTS[2]
Powders and flakes	618.4000	7603.10.0000
	618.4200	7603.20.0000
Wire and cable	618.2100	7605.11.0030
		7605.11.0090
		7605.19.0000
		7605.21.0030
		7605.21.0090
		7605.29.0000

[1] Tariff Schedules of the United States Annotated.
[2] Harmonized Tariff System of the United States.

Source: Bureau of the Census.

On January 1, 1989, the Harmonized Tariff System went into effect. This system was designed to bring the trade classifications used in the United States closer to those used in the rest of the world. Tables 29 and 32 provide listings of the tariff codes used by the Bureau of Mines to prepare trade data before January 1 and those that were used under the new Harmonized System.

World Review

World aluminum demand slowed from levels reached during the past few years but remained strong. Inventories in market economy countries increased slightly over last year's levels but remained at historically low levels. Many of the world's producers of aluminum continued to operate their primary smelters at or near rated capacity levels.

Primary aluminum inventories held by members of the International Primary Aluminium Institute (IPAI), which represent the bulk of stocks held outside the centrally planned economy countries, increased slightly from 1.482 million tons at yearend 1988 to 1.576 million tons at yearend 1989. IPAI reported that total metal inventories, including secondary aluminum, increased from 3.085 million tons at yearend 1988 to 3.231 million tons at yearend 1989.

Capacity.—The data in table 35 are rated annual capacity for plants producing primary aluminum metal as of December 31 for the years shown. Rated capacity is defined as the maximum quantity that can be produced on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures for labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Greenfield smelter expansions were planned for areas of the world that had low energy and/or labor costs, most notably Canada and the Persian Gulf area.

Algeria.—A Dubai-based consortium, Industrial Development Corp. of Dubai, and the Algerian Public National Enterprise announced plans to build a 220,000-ton-per-year smelter and related facilities, including a powerplant and port, on the western coast of Algeria. Work on the facility, to be named Medial, was expected to start in late 1990 and take 3 years to complete. Members of the consortium were reported to be Caradel Investments Inc., George Wimpey Plc., Asea Brown Boveri, and the Marc Rich organization.

Australia.—Kaiser Aluminium announced the sale of its 20% interest in the Boyne Island smelter at Gladstone to Austria Metall AG.

Tomago Aluminium Co. Pty. Ltd. announced that it was investigating the possibility of constructing a third potline at its 230,000-ton-per-year smelter in New South Wales that would increase capacity to 360,000 tons per year. Startup of the additional potline reportedly depended on the signing of a power contract with the New South Wales Electricity Commission.

Comalco announced that a prefeasibility study for a 198,000-ton-per-year expansion at the Boyne Island smelter had been completed. Comalco reportedly was investigating the possible purchase of the Gladstone power station to ensure the power required for the planned expansion.

Bahrain.—Kaiser Aluminum announced the sale of its 17% interest in Aluminium Bahrain (Alba) to the Government of Bahrain. The sale increased the Government's share in the 205,000-ton-per-year primary smelter to 75%. Alba also announced expansion plans for the smelter that would increase capacity to 460,0000 tons per year by 1992.

Brazil.—Reynolds Metals announced the sale of all but a 35% interest in

TABLE 30

U.S. EXPORTS OF ALUMINUM, BY CLASS[1]

Class	1988		1989	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	400,057	$925,572	593,048	$1,260,638
Scrap	486,615	774,277	574,170	767,573
Plates, sheets, bars, strip, etc.[2]	334,395	995,767	416,241	1,195,015
Castings and forgings	16,964	111,168	20,480	128,975
Semifabricated forms, n.e.c.	9,306	50,669	9,368	55,075
Total	1,247,337	2,857,453	1,613,307	3,407,276
Manufactures:				
Foil and leaf	52,307	78,912	39,334	73,708
Powders and flakes	4,445	19,472	3,262	15,949
Wire and cable	4,160	15,823	4,553	19,087
Total	60,912	114,207	47,149	108,744
Grand total	1,308,249	2,971,660	1,660,456	3,516,020

[1] Because of the implementation of the Harmonized Tariff System beginning in Jan. 1989, export categories for 1988 are not necessarily comparable with those in 1989.
[2] Includes "strip" with plates, sheets, bars, etc. in 1989.

Source: Bureau of the Census.

TABLE 31

U.S. EXPORTS OF ALUMINUM, BY COUNTRY

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1988:								
Belgium	5,243	$13,541	809	$4,253	4,094	$7,332	10,146	$25,126
Brazil	252	573	1,884	11,958	746	924	2,882	13,455
Canada	29,756	83,720	210,524	607,678	30,689	33,306	270,969	724,704
Colombia	199	574	1,929	5,095	47	86	2,175	5,755
Dominican Republic	372	773	389	957	12	11	773	1,741
France	176	707	1,923	16,059	12,814	22,628	14,913	39,394
Germany, Federal Republic of	1,227	5,087	4,437	23,923	4,280	6,360	9,944	35,370
Hong Kong	1,023	2,078	11,513	31,940	922	1,496	13,458	35,514
Italy	77	281	2,611	18,470	8,575	11,711	11,263	30,462
Japan	303,120	673,326	15,281	62,234	268,846	441,645	587,247	1,177,205
Korea, Republic of	10,108	25,197	17,532	57,582	35,663	75,627	63,303	158,406
Mexico	13,966	32,038	31,176	86,608	29,859	37,703	75,001	156,349
Netherlands	10,434	26,966	2,957	13,801	13,150	26,980	26,541	67,747
Panama	82	836	605	1,756	193	439	880	3,031
Singapore	10,328	25,175	642	9,829	1,705	3,718	12,675	38,722
Spain	24	78	1,170	6,040	330	482	1,524	6,600
Taiwan	7,054	16,762	8,903	28,006	65,823	87,946	81,780	132,714
Trinidad[2]	163	462	173	738	14	57	350	1,257
United Kingdom	1,391	3,328	8,027	45,339	1,993	3,610	11,411	52,277
Other[r]	5,062	14,070	38,180	125,338	6,860	12,216	50,102	151,624
Total	400,057	925,572	360,665	1,157,604	486,615	774,277	1,247,337	2,857,453
1989:[3]								
Belgium	2,944	6,889	1,129	5,191	4,851	6,239	8,924	18,319
Brazil	127	988	2,430	13,833	3,642	4,606	6,199	19,427
Canada	28,491	76,163	260,718	689,586	36,854	41,335	326,063	807,084
Colombia	439	927	1,510	3,940	31	47	1,980	4,914
Dominican Republic	130	354	1,143	3,025	58	126	1,331	3,505
France	265	1,635	3,274	23,817	16,522	20,602	20,061	46,054
Germany, Federal Republic of	723	3,050	5,719	23,876	9,669	12,558	16,111	39,484
Hong Kong	2,964	6,548	10,468	30,483	1,150	1,279	14,582	38,310
Italy	173	735	6,238	36,530	13,000	15,908	19,411	53,173
Japan	444,617	932,457	24,838	85,566	337,163	488,503	806,618	1,506,526
Korea, Republic of	25,012	51,054	19,010	63,480	13,983	18,916	58,005	133,450
Mexico	19,188	44,076	40,721	139,115	26,509	38,150	86,418	221,341
Netherlands	14,619	29,433	2,726	12,168	11,503	17,250	28,848	58,851
Panama	394	877	910	2,719	35	73	1,339	3,669
Singapore	5,566	9,784	1,673	19,021	453	565	7,692	29,370
Spain	179	1,602	985	5,665	1,292	1,605	2,456	8,872
Taiwan	26,706	50,985	15,301	37,099	75,429	77,768	117,436	165,852
Trinidad and Tobago[2]	203	588	364	1,156	30	28	597	1,772
United Kingdom	2,137	4,898	8,303	40,937	5,122	6,619	15,562	52,454
Other	18,171	37,595	38,629	141,858	16,874	15,396	73,674	194,849
Total	593,048	1,260,638	446,089	1,379,065	574,170	767,573	1,613,307	3,407,276

[r] Revised.

[1] Includes castings, forgings, and unclassified semifabricated forms.

[2] For 1989, Trinidad and Tobago combined, data not available to separate; 1988 data for Trinidad only.

[3] Because of the implementaion of the Harmonized Tariff System beginning in Jan. 1989, export categories for 1988 are not necessarily comparable with those in 1989.

Source: Bureau of the Census.

TABLE 32

TARIFF CODES FOR U.S. IMPORTS OF ALUMINUM

Material	1988 TSUS[1]	1989 HTS[2]
Metals and alloys, crude	618.0100	7601.10.3000
	618.0200	7601.10.6000
	618.0400	7601.20.3000
	618.0610	7601.20.6000
	618.0630	7601.20.9030
	618.0650	7601.20.9045
	618.4500	7601.20.9090
Plates, sheets, bars, etc.:		
Plates, sheets, bars, strips, etc., n.e.c.	618.1700	7606.11.3030
	618.2520	7606.11.3060
	618.2550	7606.11.6000
	618.2560	7606.12.3030
	618.2563	7606.12.3060
	618.2580	7606.12.3090
	618.2720	7606.12.6000
	618.2740	7606.91.3030
	618.2760	7606.91.3060
	618.2765	7606.91.3075
	618.2900	7606.91.3090
		7606.91.6020
		7606.91.6040
		7606.91.6060
		7606.91.6080
		7606.92.3030
		7606.92.3060
		7606.92.3075
		7606.92.3090
		7606.92.6020
		7606.92.6040
		7606.92.6060
		7606.92.6080
		7616.90.0060
		7616.90.0070
Pipes, tubes, etc.	618.4700	7608.10.0030
	618.4800	7608.10.0090
		7608.20.0030
		7608.20.0090
		7609.00.0000
Rods and bars	618.1520	7604.10.1000
	618.1540	7604.10.3010
	618.2540	7604.10.3050
		7604.10.5030
		7604.10.5060
		7604.21.0000
		7604.29.1000
		7604.29.3010

See footnotes at end of table.

TABLE 32—Continued

TARIFF CODES FOR U.S. IMPORTS OF ALUMINUM

Material	1988 TSUS[1]	1989 HTS[2]
Rods and bars—Continued		7604.29.3050
		7604.29.5030
		7604.29.5060
Scrap	618.1000	7601.20.9075
		7602.00.0030
		7602.00.0090
Foil and leaf	644.0600	7607.11.0000
	644.0800	7607.11.3000
	644.0900	7607.11.6000
	644.1100	7607.11.9000
	644.1200	7607.19.1000
	644.2600	7607.19.3000
	644.6400	7607.19.6000
	644.6800	
	644.7200	
	644.7600	
Flakes and powders	618.4000	7603.10.0000
	618.4200	7603.20.0000
Wire	618.2000	7605.11.0000
	618.2200	7605.11.0030
		7605.11.0090
		7605.19.0000
		7605.21.0030
		7605.21.0090
		7605.29.0000

[1] Tariff Schedules of the United States Annotated.
[2] Harmonized Tariff System of the United States.

Source: Bureau of the Census.

Latasa, its aluminum can manufacturing plant that came on-stream this year, to three Brazilian banks.

Canada.—A six-member consortium announced the signing of an agreement to construct a 215,000-ton-per-year primary smelter at Sept Iles, Quebec. The members of the consortium were VAW, 20%; Austria Metall, 20%; Hoogovens Groep BV, 20%; Société Generale de Financement, 20%; Kobe Steel Ltd., 13.3%; and Marubeni Corp., 6.7%. The smelter to be called Alouette reportedly was scheduled to come on-stream in 1992.

Alumax announced plans to construct a 215,000-ton-per-year greenfield aluminum smelter at Deschambault, Quebec. Completion of the project was scheduled for 1992.

Reynolds Metals announced plans to add a 120,000-ton-per-year potline to its smelter at Baie Comeau, increasing capacity to 400,000 tons per year. The company expected the potline to be fully operational by 1991. In June, workers at the Baie Comeau smelter ratified a new 3-year labor contract that was set to expire on June 30, 1992.

Alcan Aluminium announced the purchase of a 20% stake in Moli Energy Ltd. of Vancouver, British Columbia, and the signing of an agreement to blend the technologies of Alcan's aluminum-air battery and Moli's rechargeable lithium battery. Alcan reported that the joint venture could lead to the development of a lightweight power source for an electric vehicle that could also involve the company's aluminum-structured-vehicle technology.

China.—The Government announced plans to add 80,000 tons per year of capacity to its 110,000-ton-per-year smelter at its Guizhou complex. Officials expected the expansion to be completed by 1991.

The China International Trust & Investment Corp. reportedly canceled the contract to buy a mothballed smelter in Sakata, Japan, from Sumitomo Metal Industries Ltd.

Dubai.—Dubai Aluminium Co. (Dubal) announced that construction had begun on a new potline that would increase the smelter's capacity to 235,000 tons per year by 1991.

Indonesia.—The Asahan Development Authority announced plans to build a second hydroelectric powerplant for the Inalum smelter in Sumatra. The plant, with a capacity of 180 megawatts, reportedly was scheduled for completion in 1990.

Korea, Republic of.—Aluminium of Korea Ltd. announced plans to build a 100,000-ton-per-year rolling mill. The company planned commissioning of the plant in 1992.

Netherlands.—Hoogovens Groep BV announced that it would merge its aluminum operations into a new subsidiary, Hoogovens Aluminium BV.

Norway.—Soer-Norge Aluminium A/S announced plans to expand capacity at its 66,000-ton-per-year smelter at Husnes to 100,000 tons per year. The

company noted that the project, which could take 3 to 5 years to complete, hinged on the signing of power supply contracts.

Saudi Arabia.—The Minister of Industry and Electricity reported that approval had been granted for the construction of a 220,000-ton-per-year primary smelter at Yanbu. Alujain Corp., formed by Saudi interests, reportedly would hold a 60% interest in the smelter. Gove Aluminium Ltd. reported the signing of an agreement with Alujain to supply 100,000 tons per year of alumina to the smelter. The Alusa smelter was expected to begin production in 1992.

South Africa, Republic of.—General Mining Union Corp. Ltd. (Gencor) announced that it had purchased a 30.7% interest in the Alusaf Pty. Ltd. primary aluminum smelter at Richards Bay.

Switzerland.—Swiss Aluminium Ltd. (Alusuisse) announced that the company would be renamed Alusuisse Lonza Holdings effective January 1, 1990.

Taiwan.—Ball Corp. of Muncie, IN, and Hong Kong-based Lam Soon Ltd. announced the formation of a joint venture to construct an aluminum beverage can plant in Hsin Chu County, south of Taipei. Ball reportedly would own 30% of the venture called Lam Soon-Ball International. The company expected the plant to be operational early next year and to produce 1,600 cans per minute for the local beer and soft drink market.

U.S.S.R.—Reynolds Metals, Fata European Group of Italy, and a group of U.S.S.R. organizations announced plans to build an aluminum foil production and converting operation in Siberia. The plant was expected to have a capacity of 47,000 tons per year and to be located in the town of Sajanogordsk. Six U.S.S.R. entities would own 70% of the plant, while Reynolds Metals and Fata would each own 13.5%, and the remaining 3% would be held by the San Paolo Bank of Italy.

United Kingdom.—British Alcan Aluminium Plc. announced plans to build a UBC recycling plant at Latchford Locks in northwestern England. The company expected the plant to have an annual capacity of 50,000 tons and to come on-stream in 1991.

Venezuela.—Aleaciones Ligeras SA (Alisa) reported the signing of an agreement with Davy McKee for the construction of a 120,000-ton-per-year primary aluminum smelter. Alisa is a wholly Venezuelan-owned project. Corporacion Venezolana de Guyana (CVG) reportedly owned 30% of the project, and Ripesa, an investment group, held the remaining 70%. The new startup date given by the company was 1993.

TABLE 33

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY CLASS[1]

Class	1988		1989	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value thousands)
Crude and semicrude:				
Metals and alloys, crude	1,027,246	$2,197,785	923,030	$1,898,132
Plates, sheets, strip, etc., n.e.c.[r 2]	341,508	898,386	315,564	867,222
Pipes, tubes, etc.	3,838	18,205	2,808	20,363
Rods and bars	47,113	111,622	22,012	63,331
Scrap	200,517	318,015	206,610	309,122
Total	1,620,222	3,544,013	1,470,024	3,158,170
Manufactures:				
Foil[3]	33,058	144,643	25,832	123,223
Leaf[3]	(4)	299	(3)	(3)
Flakes and powders	2,869	6,799	2,259	6,916
Wire	5,452	18,331	23,446	68,683
Total	41,379	170,072	51,537	198,822
Grand total	1,661,601	3,714,085	1,521,561	3,356,992

[r] Revised.

[1] Because of the implementation of the Harmonized Tariff System beginning in Jan. 1989, import categories for 1988 are not necessarily comparable with those in 1989.

[2] Includes plates, sheets, circles, and disks.

[3] Combining foil and leaf in 1989.

[4] 1988—aluminum leaf not over 30.25 square inches in area 5,235,781 leaves, and aluminum leaf over 30.25 square inches in area, 771,966,360 square inches.

Source: Bureau of the Census.

Current Research

Golden Aluminum published a brief description of the continuous cast process used by the company to produce can body stock at its Fort Lupton, CO, facility. The paper described chemical composition control, surface quality, internal structure, gauge, and casting parameters, as well as the operating practices required to obtain these quality levels.[12]

The Bureau of Mines studied the effects of aluminum additions on the sulfidation resistance of iron-chromium-nickel (Fe-Cr-Ni) alloys. A series of Fe-Cr-Ni alloys with and without additions of 4% aluminum were tested in a wet sulfur vapor atmosphere at 677° C. Aluminum-containing alloys formed a compact, tightly adherent layer of scale that reduced corrosion rates by a factor of 3 to 10 compared with that of aluminum-free alloys. The thin, adherent aluminum-containing scale limited inward diffusion of sulfur and oxygen to the base metal and outward diffusion of nickel from the base metal.[13]

Outlook

World supply and demand should be in fairly good balance over the next few years. Growth in world aluminum demand has slowed from the rapid growth rates of the late 1980's but should show an average growth rate of about 2% per year over the next few years. Increased attention, both domestically and abroad, to waste disposal problems should provide steady growth in the secondary aluminum industry.

TABLE 34

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1988:								
Argentina	25,088	$39,581	9,763	$23,231	—	—	34,851	$62,812
Australia	13,358	28,440	5,182	10,996	662	$1,281	19,202	40,717
Belgium	89	504	33,616	86,617	231	233	33,936	87,354
Canada	794,786	1,704,106	117,984	286,102	135,061	219,793	1,047,831	2,210,001
France	130	657	25,926	78,609	422	660	26,478	79,926
Germany, Federal Republic of	1,229	6,908	11,814	40,428	3,474	4,462	16,517	51,798
Ghana	50,543	126,417	723	1,596	—	—	51,266	128,013
Hong Kong	227	465	2,924	7,625	112	172	3,263	8,262
Israel	9	37	1,165	5,064	76	109	1,250	5,210
Jamaica	209	289	—	—	1,049	1,567	1,258	1,856
Japan	558	2,782	40,062	108,508	234	642	40,854	111,932
Mexico	7,085	15,538	5,882	17,164	17,180	21,148	30,147	53,850
Netherlands	2,167	3,581	8,978	40,750	3,224	4,332	14,369	48,663
Panama	348	342	19	21	3,967	4,739	4,334	5,102
U.S.S.R.	267	485	—	—	16,877	29,118	17,144	29,603
United Kingdom	2,000	5,524	7,063	29,739	3,955	6,284	13,018	41,547
Venezuela	52,829	106,448	36,641	81,206	8,644	15,865	98,114	203,519
Yugoslavia	431	981	12,684	31,214	—	—	13,115	32,195
Other[r]	75,893	154,700	72,033	179,343	5,319	7,610	153,275	341,653
Total	1,027,246	2,197,785	392,459	1,028,213	200,517	318,015	1,620,222	3,544,013
1989:[2]								
Argentina	12,173	23,046	6,889	17,302	—	—	19,062	40,348
Australia	5,764	12,084	11	70	666	1,588	6,441	13,742
Belgium	76	467	29,993	83,693	101	116	30,170	84,276
Canada	789,587	1,637,472	151,848	384,988	160,764	246,259	1,102,199	2,268,719
France	97	672	11,042	40,715	379	527	11,518	41,914
Germany, Federal Republic of	579	7,766	10,745	42,165	872	1,295	12,196	51,226
Ghana	8,924	21,805	278	651	—	—	9,202	22,456
Hong Kong	10	10	2,558	7,157	123	213	2,691	7,380
Israel	—	—	1,227	7,786	20	31	1,247	7,817
Jamaica	100	168	—	—	1,875	2,919	1,975	3,087
Japan	941	2,657	20,788	68,291	310	891	22,039	71,839
Mexico	733	1,650	3,028	9,564	20,798	23,993	24,559	35,207
Netherlands	2	72	5,056	24,515	20	147	5,078	24,734
Panama	481	638	—	—	3,539	4,285	4,020	4,923
U.S.S.R.	100	226	—	—	5,845	10,054	5,945	10,280
United Kingdom	356	1,789	11,470	41,960	541	1,077	12,367	44,826
Venezuela	59,552	90,694	16,454	36,612	4,747	7,800	80,753	135,106
Yugoslavia	19	50	13,289	31,320	—	—	13,308	31,370
Other	43,536	96,866	55,708	154,127	6,010	7,927	105,254	258,920
Total	923,030	1,898,132	340,384	950,916	206,610	309,122	1,470,024	3,158,170

[r] Revised.

[1] Includes circles, disks, rods, pipes, tubes, etc.

[2] Because of the implementation of the Harmonized Tariff System beginning in Jan. 1989, import categories for 1988 are not necessarily comparable with those in 1989.

Source: Bureau of the Census.

TABLE 35

ALUMINUM: WORLD ANNUAL PRIMARY METAL PRODUCTION CAPACITY, BY COUNTRY[1]

(Thousand metric tons)

Continent and country	1987	1988	1989[p]
North America:			
Canada	1,577	1,594	1,594
Mexico	66	66	66
United States	3,895	3,960	4,016
South America:			
Argentina	150	160	160
Brazil	869	869	869
Suriname	30	30	30
Venezuela	430	460	666
Europe:			
Austria	92	92	92
Czechoslovakia	60	60	60
France	346	346	346
German Democratic Republic	85	85	85
Germany, Federal Republic of	733	733	733
Greece	145	145	145
Hungary	76	76	76
Iceland	86	86	86
Italy	276	276	276
Netherlands	266	266	266
Norway	834	843	851
Poland	110	110	110
Romania	250	250	250
Spain	344	344	344
Sweden	91	91	91
Switzerland	72	72	72
U.S.S.R.	2,590	2,590	2,640
United Kingdom	287	287	287
Yugosiavia	357	367	377
Africa:			
Cameroon	80	80	80
Egypt	170	170	170
Ghana	200	200	200
South Africa, Republic of	172	172	172
Asia:			
Bahrain	180	180	205
China	r695	875	975
India	472	472	472
Indonesia	225	225	225
Iran	50	50	50
Japan	64	64	64

See footnotes at end of table.

TABLE 35—Continued

ALUMINUM: WORLD ANNUAL PRIMARY METAL PRODUCTION CAPACITY, BY COUNTRY[1]

(Thousand metric tons)

Continent and country	1987	1988	1989[p]
Asia—Continued			
Korea, North	20	20	20
Korea, Republic of	18	18	18
Taiwan	50	50	50
Turkey	60	60	60
United Arab Emirates: Dubai	149	159	170
Oceania:			
Australia	1,012	1,177	1,177
New Zealand	244	250	250
Total	r17,978	18,480	18,946

[p] Preliminary. [r] Revised.

[1] Detailed information on the individual aluminum reduction plants is available in a two-part report that can be purchased from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, CO, 80225. Part 1 of "Primary Aluminum Plants, Worldwide" details location, ownership, and production capacity for 1985-92 and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economies. Part 2 summarizes production capacities for 1985-92 by smelter and country.

BACKGROUND

Definitions, Grades, and Specifications

Bauxite is a heterogeneous material composed chiefly of the aluminum oxide minerals gibbsite ($Al_2O_3 \cdot 3H_2O$), the trihydrate, and boehmite and diaspore ($Al_2O_3 \cdot H_2O$), the monohydrates.[14] Domestic bauxites and those imported from Brazil, Guyana, and Suriname are of the trihydrate gibbsitic type. Imports from the Sangaredi deposits of Guinea and the north coast of Jamaica are predominantly gibbsitic, but they also contain 4% to 10% of the monohydrate mineral boehmite. In most European and northern Asian bauxite deposits, boehmite is the principal alumina mineral. Recovery of the aluminum oxide in boehmite requires a higher temperature and higher caustic concentration than is needed in processing gibbsite. Major impurities in bauxite ores include iron oxides, silica, aluminum silicates, and titanium oxides.

Free moisture in crude bauxite, as mined, may range from 5% to 30%. In dried bauxite, most of the free moisture is removed by heating crude bauxite in rotary drying kilns at about 315° C. Calcined bauxite is produced by heating bauxite to 925° to 1,040° C to reduce total volatile matter, including chemically combined water, to less than 1%. About 2 tons of crude ore is required to produce 1 ton of calcined bauxite.

Aluminum metal has a relatively low density, high electrical and thermal conductivity, good resistance to corrosion, and good malleability. It is nonmagnetic, nonsparking, and highly reflective. It may be alloyed and treated to yield a high strength-to-weight ratio.

Ingot is a cast form of primary or secondary metal that is convenient to handle and store and is suitable for fabricating or remelting. Commercial size ingots normally weigh about 30 pounds; however, some ingots weigh up to 9 tons. A significant portion of both primary and secondary metal is sold and transported in molten form.

Commercially pure aluminum usually contains about 99.7% aluminum. In the annealed condition, it has low strength and is relatively soft. However, it is available in strain-hardened conditions of higher strength and reduced ductility. Metal with more than 99.7% and up to 99.85% aluminum is available at higher costs than standard commercial metal. Superpurity aluminum contains a minimum of 99.99% aluminum.

Aluminum alloys have been developed that, after cold rolling, heat treating, annealing, or age hardening, have strengths approaching those of mild steels. More than 100 commercial alloys are available, and several new alloys are developed each year. The alloys offer a wide variety of combinations of mechanical strength, ductility, electrical conductivity, and corrosion resistance.

Aluminum alloys are generally divided into two major groups: wrought and casting. The Aluminum Association uses a code to designate the purity and alloy content of wrought alloys and to register the composition of casting alloys and ingot. The range of compositions of wrought aluminum alloys and selected aluminum casting ingot alloys is given in table 39.

New aluminum-base scrap, generated in the production of intermediate and end products of aluminum metal, may be pure (unalloyed), segregated (one alloy type), or mixed (two or more alloys). It

includes solids, such as new casting scrap; clippings or cuttings of new sheet, rod, wire, and cable; borings and turnings from the machining of aluminum parts; and residues, drosses, skimmings, spillings, and sweepings.

New scrap is further defined as either "runaround" (home) scrap or purchased scrap. Runaround or home scrap is new scrap that is recycled by the same company that generates it; such scrap by definition never leaves the company generating it and, therefore, is never marketed as scrap. Purchased scrap is new scrap that is purchased, imported, or treated on toll by secondary smelters, the original aluminum product suppliers, or others. New aluminum scrap that is purchased from manufacturers of end products may be referred to as consumer scrap. Purchased scrap is sometimes referred to as prompt industrial scrap.

Old scrap, all of which is considered as purchased, comes from discarded, used, and worn out products. It includes aluminum pistons or other aluminum engine or body parts from junked cars, aluminum UBC's and utensils, and old wire and cable. Sweated pig is scrap that has been sweated or melted into a pig or ingot form for convenience and economy in shipping and storage. Obsolete scrap is new, unused, but technologically obsolete aluminum end products, outdated inventory materials, production overruns, and spare parts for machines and equipment no longer being used. In the United States, both sweated pig and obsolete scrap are considered old scrap.

Geology-Resources

Bauxite is formed by the weathering of aluminum-bearing rocks under conditions conducive to the chemical breakdown of minerals in the parent rock. In the weathering process, the aluminum is retained as hydrated aluminum oxide minerals and other constituents are leached from the parent rock. Conditions favorable for the formation of bauxite existed in areas and geological periods that provided warm wet climates, parent aluminous rocks with high permeability and readily soluble minerals, good subsurface drainage, and long periods of tectonic stability that permitted deep weathering and preservation of land surfaces.

The major deposits in central Arkansas were formed by weathering of

TABLE 36

ALUMINUM, PRIMARY: WORLD PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

Country	1985	1986	1987	1988[p]	1989[e]
Argentina	136	148	153	154	155
Australia	851	882	1,004	1,150	[2]1,244
Austria	94	93	93	95	[2]93
Bahrain	176	178	180	[e]182	[2]184
Brazil	549	757	843	874	[2]935
Cameroon	90	84	79	87	86
Canada	1,282	1,355	1,540	1,535	[2]1,555
China[e]	410	410	615	800	825
Czechoslovakia	32	33	32	32	30
Egypt	209	175	179	173	173
France	293	322	323	328	[2]335
German Democratic Republic[e]	60	61	62	[r]61	60
Germany, Federal Republic of	745	765	738	744	[2]742
Ghana	49	125	150	161	[2]169
Greece[3]	[r]125	[r]124	127	151	[2]145
Hungary	74	74	76	75	75
Iceland	73	76	85	82	[2]89
India[3]	260	257	265	375	375
Indonesia[3]	217	219	202	185	222
Iran[e]	43	40	40	40	40
Italy	224	243	233	222	220
Japan[4]	227	140	41	35	[2]35
Korea, North[e]	10	10	10	10	10
Korea, Republic of[3]	18	19	22	18	17
Mexico[3]	43	[r]37	65	71	72
Netherlands	251	266	276	278	[2]274
New Zealand	241	[r]236	252	264	[2]260
Norway	743	726	806	864	[2]859
Poland[5]	47	48	48	48	47
Romania[6]	247	269	260	[e]260	250
South Africa, Republic of	165	170	171	172	170
Spain	370	350	341	323	[2]352
Suriname	29	[r]29	2	10	10
Sweden	84	[r]78	81	99	[2]97
Switzerland	73	80	73	72	[2]71
Turkey	54	60	42	57	57
U.S.S.R.[e]	2,200	2,300	2,400	2,400	2,400
United Arab Emirates: Dubai	153	155	155	162	160
United Kingdom	275	276	294	300	[2]297
United States	3,500	3,037	3,343	3,944	[2]4,030
Venezuela	396	[r]424	440	455	500
Yugoslavia[e 3]	280	282	244	260	260
Total	15,398	[r]15,413	16,385	17,608	17,980

[e]Estimated. [p]Preliminary. [r]Revised.

[1]The Bureau of Mines defines primary aluminum as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through May 23, 1990.

[2]Reported figure.

[3]Primary ingot.

[4]Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1985—4,783; 1986—8,140; 1987—12,099; 1988—13,628; and 1989—15,600 (estimated).

[5]Primary unalloyed ingot plus secondary unalloyed ingot.

[6]Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

TABLE 37

TYPICAL SPECIFICATIONS FOR GRADES OF BAUXITE

(Weight-percent, maximum content unless otherwise specified)

Constitutent	Metal grade (dried Jamaica type)	Refractory grade (calcined)	Abrasive grade (calcined)
Al_2O_3	[1]47.0	[1]86.5	[1]83.0
SiO_2	3.0	7.0	6.0
Fe_2O_3	22.0	2.5	8.0
TiO_2	3.0	3.75	[2]3.0- 4.5
$K_2O + Na_2O$	NS	.2	.7
MgO + CaO	NS	.3	NS
CaO	NS	NS	.2
MgO	NS	NS	.4
$MnO_2 + Cr_2O_3 + V_2O_5$	2.0	1.0	1.0
P_2O_5	1.5	NS	.5
Loss on ignition	NS	.5	1.0

NS No specification.
[1] Minimum content.
[2] Range of content.

TABLE 38

CELL-GRADE ALUMINA SPECIFICATIONS, IN WEIGHT-PERCENT

Impurity	Maximum content	Impurity	Maximum content
SiO_2	0.015	B_2O_3	0.001
Fe_2O_3	.015	TiO_2	.002
MnO	.002	P_2O_5	.001
NiO	.005	MgO	.002
Cr_2O_3	.002	CaO	.04
CuO	.01	Na_2O	.40
V_2O_5	.002	K_2O	.005
ZnO	.01	Chloride, residual	.05
Ga_2O_3	.02		

Source: Industry-Bureau of Mines Alumina Miniplant Steering Committee recommended specifications, May 1979.

nepheline syenite intrusives during late Paleocene and early Eocene time.[15] The predominant aluminum oxide mineral in the bauxite is the trihydrate form, gibbsite. Some deposits are residual on the igneous rock and clay, while others are the result of transportation and accumulation of eroded deposits. Most of the deposits were subsequently covered by sand and clay beds. Bauxite ore ranges in thickness from a few feet to 65 feet and is overlain by a 40- to 150-foot overburden. The composition of the ore mined in Arkansas varies widely within a range of 40% to 52% Al_2O_3, 7% to 17% SiO_2, and 6% to 12% Fe_2O_3.

The bauxite deposits in the coastal plain of Alabama and Georgia are found as lenses within flat-lying beds of kaolinitic clay, which are overlain by sand and clays of early Tertiary age. Average ore thickness is 10 feet, though locally 33-foot ore has been encountered. Overburden, especially in the Alabama sinkhole deposits, can exceed 120 feet in thickness. The grade of the bauxite is 48% to 56% Al_2O_3, 12% to 16% SiO_2, and less than 2.5% Fe_2O_3. The low iron oxide content permits this ore to be used in refractories and chemicals.

In Jamaica, the bauxite deposits fill sinkholes and channels and blanket uneven depressions in the karst surface of a limestone of middle Tertiary age. Individual ore bodies range from pockets containing a few hundred tons of bauxite to basins containing millions of tons. The soil overburden is only 1 to 2 feet thick. Jamaican bauxite is largely gibbsitic, although mixtures containing up to 20% monohydrate alumina occur. Ore grade is 45% to 49% Al_2O_3, 0.8% to 8% SiO_2, 17% to 22% Fe_2O_3, and 2.5% TiO_2. The bauxite deposits in the Dominican Republic and Haiti are similar in grade, age, and genesis, and are identified as "Jamaica-type" bauxites.

Bauxite deposits in Suriname and Guyana are scattered throughout a narrow belt extending along the contact between the Precambrian crystalline rocks of the Guyana Shield and the sedimentary beds of Tertiary or later age that form the coastal plain. These deposits usually rest on kaolinitic clay and range from exposed outcrops to ore bodies overlain by as much as 200 feet of sand and clay, although the average overburden is around 60 feet. Other deposits of bauxite and laterite occur in these countries at higher elevations south of the coastal belt. The alumina mineral is gibbsite and the ore is high grade; typically 55% to 60% Al_2O_3, 2% to 5% SiO_2, and less than 3% Fe_2O_3. Both countries have been exporters of refractory and abrasive-grade bauxite.

In the large deposits discovered in northern Brazil since 1967, the bauxite occurs as a residual capping on dissected plateaus several hundred feet above the Amazon or other nearby rivers. The ore has developed on unconsolidated Tertiary sediments and is covered by 12 to 30 feet of kaolinitic clay. Ore thickness averages about 16 feet. The approximate grade after washing is 55% Al_2O_3, 3.5% SiO_2, and 11% Fe_2O_3. Bauxites in northern Brazil and Venezuela are of the gibbstic type and contain little monohydrate alumina.

The Weipa bauxite deposit in Queensland, Australia, occurs in the upper portion of a flat-lying laterite that extends for more than a hundred miles along the west coast of the Cape York Peninsula. The bauxite ranges in thickness from a few feet to 30 feet and is covered by a soil overburden 1 to 3 feet thick. Average ore thickness is about 14 feet. The ore is basically gibbsitic, but some of the alumina is also present in the form of boehmite. The deposits are associated with Tertiary kaolinitic

sands, from which they were probably derived. The grade of the beneficiated bauxite is 53% to 58% Al_2O_3, 4% to 7% SiO_2, and 12% Fe_2O_3.

The Darling Range bauxite deposits in Western Australia occur as a residual capping on Precambrian granites, gneiss, and intrusive crystalline rocks. A thin 1.5-foot blanket of soil mixed with loose pisolites covers the deposits. The top of the ore is characterized by a ferruginous hardcap about 6 feet in thickness. The deposits are characterized by a low alumina and a high quartz sand content; however, the reactive silica is typically less than 2%. General composition is 38% to 46% Al_2O_3, 10% to 23% SiO_2, 11% to 16% Fe_2O_3, and about 4% TiO_2.

In Guinea, the large Sangaredi bauxite deposits occur as laterite caps on inland plateaus at elevations of 900 feet or more above sea level. The deposits have been dissected by stream valleys. Most of the bauxite is believed to have formed through weathering of schists and sandstones of Devonian or Post-Devonian age. The thickness of the Sangaredi bauxite ore averages more than 65 feet and exceeds 130 feet in some places. Overburden, where present, consists of a thin topsoil. Typical ore contains 57% to 60% Al_2O_3, less than 1% SiO_2, and 2% to 4% Fe_2O_3. The upper zone of the Sangaredi deposit contained only a few percent boehmite, but mining has progressed to lower benches where the monohydrate content has increased to nearly 10%.

Many of the European bauxite deposits are associated with pockets and depressions in the karst weathering surface of Mesozoic limestone beds that have been buried, folded, and faulted subsequent to the development of the bauxite. European bauxites are composed predominantly of monohydrate alumina minerals, although some gibbsitic deposits are mined in Hungary and a few other countries.

Historically, the commercial production of primary aluminum has been based almost entirely on the use of bauxite. However, deposits containing aluminum in the other mineral forms are widespread and virtually inexhaustible. The average aluminum content of the Earth's crust has been estimated at 8.3% (15.7% on an Al_2O_3 basis), and deposits containing more than 13% aluminum (25% Al_2O_3) are common.

Information on bauxite reserves and

TABLE 39

COMPOSITION LIMITS AND USES OF SOME ALUMINUM WROUGHT AND CASTING ALLOYS[1]

(Weight-percent)

Aluminum Association designation	Aluminum	Copper	Manganese	Magnesium	Silicon	Other constitutents	Applications
Wrought alloy series:							
1000	99.00-99.75	0.2	0.05	0.05	[2]1.0	0.1 zinc, 0.05 titanium.	Electrical conductor, chemical equipment, cooking utensils.
2000	Balance[3]	1.9-1.2	0.2-1.8	0.02- 1.8	0.1- 1.2	1.3 iron, 0.2 titanium, 2.3 nickel.	Forgings, aircraft, rocket fuel tanks.
3000	do.[3]	.3	.3-1.5	.2- 1.3	.6	0.4 zinc, 0.1 titanium, 0.7 iron.	Ductwork, can bodies, hydraulic tubing.
4000	do.[3]	.10-1.3	.05-1.3	3.6-13.5	3.6-13.5	1.3 nickel, 0.2 zinc.	Welding and brazing wire, pistons.
5000	do.[3]	.2	.01-1.0	.5- 5.6	.45	0.35 chromium, 0.2 titanium, 7 iron.	Bus and truck bodies, screens, pressure vessels, aircraft tubing.
6000	do.[3]	.1-1.2	.03-1.1	.35- 1.5	1.8	2.4 zinc, 1.0 iron.	Heavy-duty structures, pipe, bus bars.
7000	do.[3]	.05-2.6	.1- .7	.1- 3.4	[2].7	0.35 chromium, 8.0 zinc, 0.2 titanium.	Aircraft structurals and skins.
Diecasting ingot:[4]							
A380	do.[3]	3.0-4.0	.5	.1	7.5- 9.5	0.5 nickel, 3.0 zinc, 1.3 iron.	General purpose castings.
A413	do.[3]	1.0	.35	.1	11.0-13.0	0.5 nickel, 0.5 zinc, 1.3 iron.	Large instrument cases.
Sand and permanent mold casting ingot:[4]							
342	do.[3]	3.5-4.5	.35	1.2- 1.8	1.0	2.3 nickel, 0.35 zinc, 0.25 titanium.	Cylinder heads, engine pistons.
356	do.[3]	.25	.35	.2- .4	6.5- 7.5	0.6 iron, 0.35 zinc, 0.25 titanium.	Automative transmission cases, aircraft and marine fittings.

[1] Maximum weight-percent of the casting ingot or at least one of the wrought alloys in the series unless a range is given, in which case the upper and lower limits do not necessarily apply to the same alloy in the series.
[2] Includes iron.
[3] Balance after deducting percent composition of specified alloying constitutents, plus other normal impurities. Minimum impurities for casting alloys are normally specified but are not shown in this table.
[4] Composition of castings may differ from that of the ingot.

resources varies from reports based on thorough exploration for some deposits to reports giving only a total quantity estimate based on unspecified fieldwork for other deposits. The reserve and reserve-base estimates in table 40 are the result of evaluating data and information obtained from many sources. The quality of bauxite deposits cannot be assessed by the alumina content alone because the mineralogical form in which the alumina occurs, its extractability in the Bayer process, the quantity of reactive silica present, iron content, including the ratio of ferric to ferrous iron, and other chemical and physical properties all affect the process cost and the alumina recoverable from a given bauxite. The classification of undeveloped bauxite deposits as either reserves or subeconomic resources also is a matter of judgment because many factors other than grade influence the economics of mining, transporting, and processing the bauxite to alumina. The definitions of reserves and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals."[16]

Past estimates of world bauxite reserves were about 1 billion metric tons in 1945, nearly 3 billion tons in 1955, 6 billion tons in 1965, and about 21 billion tons in 1985. In 1989, they were estimated at about 22 billion tons. Guinea and Australia together have about one-half of the world's reserves. More than 25% occurs in the Western Hemisphere, principally in Brazil, Jamaica, Guyana, and Suriname. Estimates of additional bauxite classified as subeconomic, hypothetical, or speculative resources bring the total world resources of bauxite to 55 to 75 billion tons. Growth in reserves has roughly paralleled the expansion of world bauxite production capacity. Major new discoveries are the primary factor in reserve increases; however, production economies resulting from technological advances and large-scale operations have also permitted the inclusion of lower grade bauxite previously considered subeconomic.

The principal domestic deposits of bauxite are in central Arkansas, where reserves are estimated to be about 33 million metric tons. An additional 2 to 5 million tons of bauxite reserves in Alabama and Georgia are the source of domestic refractory and chemical bauxites.

The resources of bauxite in the United States, other than the present reserves, are chiefly in (1) large low-grade deposits containing substantial quantities of clay minerals and deeply buried and thin deposits in Arkansas, Alabama, and Georgia; (2) ferruginous bauxite deposits in Oregon and Washington; and (3) deposits of low-grade ferruginous bauxite in soils and weathered basalts on Kauai and Maui, Hawaii. Inclusion of these low-grade resources increases the total estimated bauxitic resource in the United States to 300 to 325 million tons. The mining of some of these deposits may be restricted or prohibited because of environmental considerations such as their proximity to populated or scenic areas.

Nonbauxitic aluminum-bearing deposits in the United States that have received the most attention as potentially economic sources of aluminum include kaolinitic clays, anorthosite, and alunite. Other types of clays, shales, schists, nepheline syenite, and sapprolite are also potential aluminum raw materials. In addition, the production of certain other minerals yields aluminous materials that may be considered potential sources of metal. These include coal ash and coal mining refuse, copper leach solutions, aluminum phosphate rock, and dawsonite if produced in conjunction with the mining of oil shales.

TABLE 40

WORLD BAUXITE RESOURCES, DECEMBER 1989

(Million metric tons of bauxite)

Continent and country	Reserves[1]	Reserve base[1]
North America and Caribbean Islands:		
Dominican Republic	30	45
Haiti	10	14
Jamaica	2,000	2,000
United States	38	40
South America:		
Brazil	2,800	2,900
Guyana	700	900
Suriname	575	600
Venezuela	320	350
Europe:		
France	30	40
Greece	600	650
Hungary	300	300
Italy	5	5
Romania	50	50
Spain	5	5
U.S.S.R.	300	300
Yugoslavia	350	400
Africa:		
Cameroon	680	1,000
Ghana	450	560
Guinea	5,600	5,900
Mozambique	2	2
Sierra Leone	140	160
Zimbabwe	2	2
Asia:		
China	150	1,450
India	1,000	1,200
Indonesia	750	805
Malaysia	15	20
Pakistan	20	20
Turkey	25	30
Oceania:		
Australia	4,440	4,600
Other	200	200
Total[2]	22,000	25,000

[1] Resource Reserve Definition. Geological Survey Circular 831, 1980.

[2] Data may not add to totals shown because of independent rounding.

Technology

Exploration.—The first stage of planning a bauxite exploration program usually entails a thorough study of regional geology, physiography, and any previous reports on exploration or mining operations within the area of interest. The initial regional appraisal should include a review of topographic maps (rarely available for remote tropical areas), aerial photographs, satellite images, and mosaics prepared from aerial side-looking radar (SLR) surveys. In the Amazon Basin of Brazil, where the dense rain forest canopy completely masks stream valleys, scarps, and plateaus, SLR methods have proven effective in revealing the hidden topography. Geobotanical techniques using real or false color air photos and satellite images have been used to identify vegetation types associated with aluminous laterites. Airborne radiometric surveys are useful in delineating exposed laterites by their typically evaluated levels of radioactivity.

After specific target areas have been

defined, reconnaissance by helicopter or fixed-wing aircraft can provide valuable logistics information. Surface prospecting for float samples in stream valleys has long been a reliable guide in the discovery of bauxite deposits. Vertical channel sampling of indurated resistant outcrops exposed in stream valleys can often provide the first positive identification of the presence of bauxite. Detailed evaluation and development require drilling, pitting, or trenching to provide samples for chemical analysis. Surface mapping is essential to document drill collar and pit locations and elevations.

Bauxite minerals are difficult to identify visually and require sophisticated laboratory techniques for quantitative analysis. Because of this requirement, exploration samples and development samples are often shipped to the company's main laboratory for analysis. The most important determinations are for alumina and silica content. Both "total alumina" and "available alumina" (alumina recoverable by both low- and high-temperature Bayer processes) are normally determined. In addition to "total silica," it is important to analyze for "reactive silica" because the latter combines with alumina and soda in the Bayer process to form sodium aluminum silicates that are lost in the red mud wastes. Iron oxides, titania, and loss on ignition are also routinely determined.

Mining.—Open pit mining accounted for all of the bauxite mined within the United States in recent years and for about 95% of the world bauxite production. Restoration of the land surface of depleted bauxite mines is being practiced in many areas of the world by preserving the topsoil after stripping for later replacement.

In Arkansas, draglines, scrapers, shovels, and trucks are used in stripping operations. Stripping ratios as high as 13 feet of over-burden to 1 foot of ore have been employed, and some surface pits in Arkansas have reached depths of about 200 feet. The pit walls of unconsolidated sand and clay are relatively stable; however, some slumping does occur. In the past, a deeper flat-lying ore was recovered by room-and-pillar mining along a retreating cave line. Underground bauxite mining ceased in 1976, and the remaining surface mining operations in Arkansas are scheduled for permanent closure in 1990.

In Jamaica, the bauxite deposits lie closer to the surface, and the overburden of vegetation and topsoil is easily stripped. The ore usually requires no blasting. Shovels, draglines, and scrapers are used to load the ore. Haulage is by truck, railroad, or aerial tramline to the alumina plants and port facilities. In Suriname and Guyana, up to 200 feet of overburden is stripped by draglines, scrapers, bucket wheel excavators, or hydraulicking. The ore is broken by blasting and loaded into ore cars or trucks with power shovels, backhoes, or draglines.

At Weipa, Australia, bulldozers and scraper loaders remove the few feet of overburden. Front-end loaders, each mining in excess of 500 tons per hour, then load the uncemented pisolitic ore into trucks for a short haul to a beneficiating plant for sizing and washing. At the deposits in the Darling Range of Western Australia, forest clearing of vegetation and overburden removal are followed by blasting of the hardcap that comprises the top few feet of the bauxite deposits. Front-end loaders load dump trucks for haulage to a mobile crushing plant. Bauxite is carried from the crusher to an alumina plant by conveyer belt.

The deposits mined for the Boké project in Guinea have little overburden, but require blasting. Loosened ore is loaded by electric shovels directly onto railcars for shipment 85 miles to a treatment plant and port at Kamsar.

Underground mining accounts for much of the Greek, French, and Hungarian bauxite production and is widely used in other parts of Europe, including the U.S.S.R. Room-and-pillar and various stoping methods are used. Underground water problems are common —especially in the Hungarian mines where bauxite deposits are associated with the weathering of limestone. Here dewatering of underground workings accounts for 10% to 15% of the mining cost.

Beneficiation.—Bauxite treatment is usually confined to crushing, washing, and drying operations. Most of the bauxites that are mined do not require the more costly beneficiation techniques used on some other metal ores. Moreover, most impurities such as iron, silicon, and titanium are frequently so finely dispersed in the bauxite that they cannot be readily separated by physical methods. Many bauxites are upgraded, however, by washing or wet screening to remove sand and some of the clay minerals.

Metallurgical and chemical grades of bauxite that must be transported appreciable distances are normally dried before shipment. Drying facilitates the handling of some bauxites, and the degree to which a specific bauxite is dried depends in part on its handling and dusting characteristics. Because crude bauxite may contain 10% to 30% free moisture, drying results in savings in freight that may more than offset drying costs. Suriname and Guinea bauxite is dried to 3% to 6% moisture, whereas Jamaican bauxite is shipped with about 15% moisture. Bauxite for use in refractories and abrasives is calcined to remove both free moisture and chemically combined water.

Alumina Production.—Virtually all commercially produced alumina from bauxite is obtained by a process patented by Karl Bayer in 1888 (German Patent 43,977), although research on aluminum extraction from other mineral raw materials has continued for many years. The Bayer process involves a caustic leach of the bauxite at elevated temperature and pressure, followed by separation of the resulting sodium aluminate solution and selective precipitation of the aluminum as the hydrated aluminum oxide ($Al_2O_3 \cdot 3H_2O$).

The actual processing conditions such as the leach temperature, holding time, and caustic concentration, as well as the costs, are influenced by the type of bauxite to be processed. As a result, a Bayer alumina plant is designed to treat a specific bauxite and, in general, cannot use a bauxite that is too different from the one the plant was designed to use without major plant modifications.

The Bayer process is initiated by mixing crude bauxite with preheated spent leach solution. Lime is added during this initial step to control the phosphorus content and to increase the solubility of alumina. The resulting slurry, containing 40% to 50% solids, is pumped with additional caustic leach solution to pressurized digesters where high-pressure steam is used to raise the temperature. Alumina and some of the silica are dissolved during this step,

soluble sodium aluminate is formed, and a complex sodium aluminum silicate is precipitated.

Digestion, in tanks 10 to 15 feet in diameter and up to 90 feet high, takes up to 5 hours. Leaching temperatures range from about 105° C to about 290° C, with corresponding pressures ranging from about 60 pounds per square inch (psi) to more than 1,000 psi. The lower temperature ranges are used for bauxites in which nearly all of the available alumina is present as gibbsite. The higher temperatures are needed to digest bauxite having a large percentage of boehmite. Caustic concentration of the spent leach solution, expressed as grams per liter of sodium carbonate (Na_2CO_3), averages about 200 grams per liter for gibbsitic bauxite and about 300 grams per liter for bauxites with a high-boehmite content.

The resulting slurry of sodium aluminate solution and insoluble red mud from the digesters is cooled to atmospheric boiling temperature, and a coarse sand waste fraction is removed by gravity separators or wet cyclones. The fine solids in the red mud are then separated by decantation of the overflow in settling tanks measuring about 15 feet in depth and 50 to 125 feet in diameter. A flocculant such as starch is added to increase the settling rate of the red mud particles. The overflow from the settling tanks containing the alumina in solution is clarified by filtration and placed into precipitating tanks ranging in size from 25 to 30 feet in diameter and up to 80 feet high.

The clarified sodium aluminate liquor is cooled until it becomes supersaturated, then seeded with fine crystals of alumina trihydrate. The alumina is precipitated as the trihydrate, separated by sedimentation or filtration, and washed. The spent leach solution containing caustic soda is regenerated in the precipitation step, and together with the alumina remaining in solution, is recycled to the digesters. The filtered and washed alumina trihydrate is calcined for use in making metal. A portion of the washed alumina may be left in the trihydrate form for chemical uses or it may be further processed under controlled conditions to produce a variety of chemical aluminas, such as activated or tabular alumina for uses other than metal production.

Two forms of calcined alumina are used to produce aluminum. European Bayer plants have traditionally produced a fine-grained, highly calcined, floury alumina while North American Bayer plants have always produced a coarser grained, porous, sandy alumina that has not been totally calcined to the alpha alumina stage (artificial corundum). The relatively large surface area of the sandy alumina particles compared with the floury alumina particles permits their use as an absorbent in dry scrubber units at the smelter. Fluorine in the gases emitted by the potlines is trapped by the alumina and is later recycled when the alumina is used as feed for the cell. Pressure from environmental regulations and improved economics through recovery of fluoride have been important factors in the conversion of world alumina plants to produce a sandy rather than a floury alumina product.

The red mud contains Fe_2O_3, TiO_2, the sodium aluminum silicate complex, and small quantities of other metal oxides. Because the complex represents a loss of both alumina and soda, a low reactive silica content in the bauxite is desirable. Reactive silica contents of more than 8% are usually uneconomic for treatment by the Bayer process because approximately 1.1 units (weight unit) of alumina and 1.2 units of soda are lost for each unit of reactive silica in the ore. The loss of soda is made up by adding caustic soda or soda ash and lime to the spent leach solution to bring it up to the appropriate caustic concentration before it is recycled.

Bauxite with 8% to 15% silica may be treated by the combination process developed by Alcoa. In this process, the bauxite is first subjected to a Bayer leach. The resulting red mud, containing sodium aluminum silicate, is sintered with limestone and soda ash and then leached with water to recover alumina and soda. Alumina produced by the combination process is of relatively high purity and commands a premium price. The insoluble residue (brown mud) resulting from leaching the sintered materials has a composition somewhat similar to that of portland cement.

The upper limit of silica for use in the combination process is about 15%. However, in practice, bauxite containing some clay and as much as 25% silica is mined and blended with low-silica ore in proportions that will give a feed material approximately 12% to 13% silica. The combination process is currently used in one plant in Arkansas, which has been scheduled for permanent closure in 1990, and reportedly in several plants within the U.S.S.R.

In the U.S.S.R., alumina is extracted from nepheline [$(Na,K)AlSiO_4$] flotation concentrates and other nonbauxitic materials containing about 30% alumina. Nepheline syenite has been mined at Belogorsk in Siberia and obtained as a byproduct of apatite recovery from syenite deposits in the Kola Peninsula. The process used involves sintering the nepheline with lime followed by leaching. Alumina reportedly is also produced from alunite [$KAl_3(OH)_6(SO_4)_2$] in the Azerbaijan S.S.R.

Historically, a small tonnage of alumina has been extracted commercially in Norway from high-iron bauxites by the Pedersen process. In this process, bauxite, limestone, coke, and iron ore are smelted in an electric furnace to produce pig iron and calcium aluminate slag containing 30% to 50% alumina. The slag is leached with sodium carbonate solution, and alumina trihydrate was precipitated by carbon dioxide. During World War II, the process was also used at a Swedish plant to treat andalusite (Al_2SiO_5).

Smelting

Primary Aluminum Production.— Primary aluminum is produced by the reduction of alumina by electrolysis in a molten bath of natural or synthetic cryolite (Na_3AlF_6), which serves as an electrolyte and as a solvent for the alumina. The reduction cells or pots containing the bath are about 10 to 15 feet wide, 20 to 40 feet long, and about 3 to 4 feet deep, lined with carbon, and connected in electrical series of 100 to 240 cells to form a potline. From 800 to 3,000 pounds of aluminum are produced per day in each pot. The carbon lining is in contact with the molten aluminum metal and serves as the cathode. It usually must be replaced after 3 to 4 years.

Cryolite and aluminum fluoride are added to the electrolyte to maintain the desirable ratio of sodium and aluminum fluoride and to replace fluorine lost from the cell in pot linings or

through volatilization. The melting point of the bath is lowered by the addition of small quantities of fluorspar or, in some instances, lithium compounds. The carbon anode, which is consumed during the operation, is replaced using the Soderberg continuous method or the prebaked method.

In the Soderberg method, a reinforced rectangular steel shell, approximately 3 to 5 feet high and open at the top and bottom, is suspended above the furnace. The carbon mass of paste or briquets of coke and pitch within the shell forms the anode and is added periodically as the anode is consumed. Current enters the anode through rows of pins inserted into the carbon mass either vertically or horizontally. The heat of the bath and the heat resulting from the electrical resistance of the carbon bake the anode mass so that it becomes a hard monolithic mass from the surface of the electrolyte to a point approximately 20 inches above the bath. As the carbon anode is consumed and additional carbon descends through the rectangular steel shell and is consumed, the lowest pins are withdrawn and replaced at higher levels in the carbon mass. The optimum anode-cathode distance is maintained by raising or lowering the cathode mass via the pins, which become baked into the lower part of the carbon block.

In the prebaked anode system, sets of 16 to 24 prebaked carbon blocks are used for the anode. The size of the blocks varies from plant to plant; typical blocks are about 20 inches wide, about 30 inches long, and 12 to 18 inches high. They weigh 400 to 600 pounds. Steel stubs or rods, which suspend the block in the bath and conduct the current to the carbon, are sealed in the anode block by pouring molten iron around the rod and allowing it to solidify. The blocks are raised or lowered separately to maintain proper position with respect to the bath and are replaced individually as they are consumed.

The Soderberg system requires less labor and, except for moving the steel pins, is a continuous method of feeding anode carbon. The prebaked system results in better electrical efficiency in the reduction cell but requires separate anode fabricating and rodding facilities not required in the Soderberg system. The prebaked system permits efficient collection of the cell offgases for subsequent treatment to remove fluorine; the offgases from a Soderberg cell are difficult to collect, necessitating fluorine recovery from a larger volume of gas than that required in prebaked systems.

The molten bath or electrolyte may be as deep as 14 inches, but the anode is usually only 2 inches from the pad of molten aluminum collecting on the carbon cathode. The optimum operating temperature is between 950° to 985° C. At this temperature range, the alumina content of the bath ranges from 3% to 10%. When the alumina concentration drops to about 2%, the electrical resistance of the cell increases sharply, chiefly because of a gas film that envelops the anode, and the voltage drop across the cell increases from 5 volts to 30 to 40 volts. The phenomenon is known as the "anode effect," and as soon as it occurs, the crust of frozen cryolite on top of the bath is broken and more alumina is added to the cell, which then returns to normal operating condition.

Every 1 or 2 days the molten aluminum is removed from the bottom of the cell by a vacuum siphon technique. Thermally insulated cast-iron pots with airtight lids and downward-sloping spouts are used to withdraw the molten metal. The pot is evacuated, and the molten metal is sucked into the cast-iron pot. The molten metal is blended in a holding furnace with other batches and alloyed and cast into various solid forms or transported molten to fabricating plants as far as 300 miles away.

Utilizing direct current, cells operate at 65,000 to 150,000 amperes; the majority of plants have 80,000- to 100,000-ampere cells. Anode current densities range from 600 to 800 amperes per square foot. The voltage drop across a single cell is 4.5 to 5.0 volts; across a potline, it may be as high as 1,000 volts.

The larger cells require less labor per pound of aluminum produced, but special problems are encountered in cells designed to operate at 100,000 or more amperes. The larger currents cause powerful magnetic fields in the molten aluminum metal and the bath, resulting in violent agitation. This agitation causes aluminum to be dispersed in the bath, increasing the possibility of reversing the reduction reaction. Another detrimental effect is that the molten metal piles up toward the negative leads, causing a variation in the anode-cathode spacing. Moreover, localized thermal effects may distort the carbon lining.

Production cells normally have current efficiencies ranging from 85% to 93%. Metal losses are principally caused by reoxidation of aluminum in the electrolyte and by physical loss of metal through vaporization from the bath or spillage. The resistance of the bath is sufficient to maintain the operating temperature. However, heat energy is lost by radiation, thermal conductance through electrode connections, in exhaust gases and tapped metal, and in electrodes removed from the cells.

To prevent atmospheric pollution, fumes evolved from the cells during electrolysis are removed from plant offgases by a collection and wet-scrubbing system or by a dry process whereby the fluorine is absorbed by alumina and recycled.

Superpurity Aluminum Processing.—The production of superpurity aluminum, 99.99+% purity, requires special procedures, such as a continuous electrorefining of commercially pure aluminum in a Hoopes cell. This cell employs three molten layers of metals or bath materials of different densities. The bottom layer is the anode, a relatively impure aluminum alloyed with copper to increase its density. The intermediate layer is molten cryolite electrolyte with alkaline earth metal fluorides added to give the desired density, always greater than pure aluminum. The top layer, which serves as the cathode, is the molten superpurity aluminum that floats on the electrolyte layer.

Recycling.—In recycling, aluminum-base scrap is usually melted in gas- or oil-fired reverberatory furnaces of 30,000 to 100,000 pounds capacity, sometimes with primary ingot metal. The furnaces have one or two charging wells separated from the main bath by a refractory wall that permits only molten metal into the main bath. The principal refining of aluminum-base scrap is the removal of magnesium by treating the molten metal with chlorine or with various fluxes such as aluminum chloride, aluminum fluoride, or mixtures of sodium and potassium chlorides and fluorides. To facilitate handling, a significant proportion of the old aluminum scrap, and in some

cases new scrap, is simply melted to form a solid ingot called "sweated pig," which must be further treated to produce specification-grade ingot.

Aluminum drosses containing about 30% metallics are usually crushed and screened to bring the metallic content up to about 60% to 70%. They are then melted in a reverberatory furnace, with the molten aluminum metal collecting on the bottom of the furnace. Salt slags containing less than 30% metallics may be leached with water to separate the metallics.

Economic Factors[17]

Aluminum production costs at aluminum mining and primary processing facilities were affected by internal factors such as variations in bauxite type and quality, stripping ratios, caustic soda consumption rates, and energy and alumina costs. In addition, external factors such as foreign exchange rates, inflation, and world market prices for products affected aluminum producers. The Bureau's Minerals Availability Program (MAP) monitors these factors to determine variations in the industry and changes in the cost competitiveness of major aluminum producing countries.

Table 41 summarizes the principal production costs of aluminum for selected countries in average 1988 U.S. dollars. The wide spread in electric power costs among primary aluminum operations was a principal reason for large variations in aluminum ingot production costs among producing nations. As a result, many energy-intensive plants have closed since 1980, and operating facilities have implemented energy-conserving technology. Countries with lower energy costs appeared to have a cost advantage over other producers.

Extreme variations in inflation relative to foreign exchange rates were another factor affecting production costs in countries such as Brazil. Although energy was abundant and labor and supply costs in Brazil traditionally have been low, extreme inflation in 1988 and 1989 made Brazil a higher-cost producer when costs were reported in U.S. dollars.

In terms of relative costs competitiveness in 1988, Australia and Canada were the lowest cost aluminum producers, principally because of low-cost energy and lower alumina and supply costs. Latin American countries such as Brazil have traditionally been low-cost producers; Brazil's costs, in the midcost range, reflected the high inflation rates present in that country in 1988. The U.S. aluminum industry also fell in the middle of the cost range, indicative of the domestic aluminum industry's recent efforts in cost reduction and restructuring. European aluminum producers appeared to be the highest cost operations.

---

[1]Federal Register. Environmental Protection Agency. Mining Waste Exclusion; Final Rule. V. 54, No. 169, Sept. 1, 1989, pp. 36591–36642.

[2]———. International Trade Commission. Calcined Bauxite Proppants From Australia. Investigation No. 731-TA-411; Final. V. 54, No. 64, Apr. 5, 1989, p. 13749.

[3]———. International Trade Commission. Dry Aluminum Sulfate From Sweden. Investigation No. 731-TA-430; Preliminary. V. 54, No. 64, Apr. 5, 1989, pp. 13749–13750.

[4]———. International Trade Administration. Final Determination of Sales at Less Than Fair Value; Aluminum Sulfate From Venezuela. V. 54, No. 205, Oct. 25, 1989, pp. 43438–43440.

[5]———. International Trade Administration. Antidumping Duty Order: Aluminum Sulfate From Venezuela. V. 54, No. 240, Dec. 15, 1989, p. 51442.

———. International Trade Administration. Countervailing Duty Order: Aluminum Sulfate From Venezuela. V. 54, No. 242, Dec. 19, 1989, p. 51908.

[6]Liles, K. J. Mechanical and Physical Properties of Particulate Composites in the System Titanium Nitride-Alumina-Aluminum Nitride. BuMines RI 9272, 1989, 7 pp.

[7]NASA Tech Briefs. Alumina-Enhanced Thermal Barrier. V. 13, No. 4, Apr. 1989, p. 78.

[8]Fulford, G. D. Scavenging Non-Filterable Iron From Bayer Liquors Using Activated Bayer Digester Sands. Paper in Light Metals 1989, ed. by P. G. Campbell, TMS-AIME, Warrendale, PA, pp. 77–89.

[9]Federal Register. Department of Transportation. Elevated Temperature Materials. V. 54, No. 182, Sept. 21, 1989, pp. 38930–38935.

[10]———. Office of the United States Trade Representative. Implementation of the Accelerated Tariff Elimination Provision in the United States; Canada Free-Trade Agreement. V. 54, No. 135, July 17, 1989, pp. 29959–29972.

[11]Bureau of Mines. Nonferrous Metal Prices in the United States Through 1988. Spec. Publ., 1989, pp. 1–4.

[12]McAuliffe, D. and I. M. Marsh. Production of Can Body Stock From Caster II Continuous Cast Strip. Paper in Light Metals 1989, ed. by P. G. Campbell, TMS-AIME, Warrendale, PA, pp. 739–741.

[13]Dunning, J. S. and S. C. Rhoads. Effects of Al Additions on Sulfidation Resistance of Some Fe-Cr-Ni Alloys. BuMines RI 9278, 1989, 19 pp.

[14]McCawley, F. X. and L. H. Baumgardner. Aluminum. Ch. in Mineral Facts and Problems, 1985 Edition. BuMines B 675, 1986, pp. 9–31.

[15]Patterson, S. H., H. F. Kurtz, J. C. Olson, and C. L. Neeley. World Bauxite Resources. U.S. Geol. Survey Prof. Paper 1076-B, 1986, 151 pp.

[16]U.S. Geological Survey and U.S. Bureau of Mines. Principles of a Resource Classification for Minerals. U.S. Geol. Survey Circ. 831, 1980, 5 pp.

[17]Prepared by David R. Wilburn, mineral specialist, Bureau of Mines, Minerals Availability Field Office, Denver, CO.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Aluminum. Ch. in Mineral Commodity Summaries, annual.

Bauxite. Ch. in Mineral Commodity Summaries, annual.

Primary Aluminum Plants Worldwide, Parts I and II, annual.

Other Sources

Aluminum Association Inc. Aluminum Statistical Review, annual.

American Metal Market (daily paper).

Industrial Minerals (London), monthly.

International Bauxite Association. IBA Review, quarterly.

Metals Week.

Roskill Information Services Ltd. Aluminum 1988, 3rd ed.

TABLE 41

ALUMINUM PRODUCTION POTENTIAL AND COSTS FOR SELECTED COUNTRIES

(Average 1988 U.S. cents per pound of aluminum)

Country	Annual production[1] (thousand metric tons)	Operating costs			Overhead	Transport to smelter	Net operating cost[2]	Recovery of capital	0% DCFROR[3]		15% DCFROR[3]		
		Labor	Supplies/ alumina	Energy					Taxes	Total cost	Taxes[4]	Return on investment	Total cost[5]
Producing operations:													
Australia	2,318	8.4	23.4	12.4	4.2	0.8	49.2	3.2	0.3	52.7	5.2	5.9	63.5
Brazil	2,407	5.0	28.3	18.0	4.9	.4	56.6	4.4	.4	61.4	2.0	8.9	71.9
Canada	3,057	11.2	25.8	5.4	3.9	.6	46.9	3.3	.5	50.7	8.7	5.9	64.8
France	639	13.4	34.2	20.5	7.0	.4	75.5	4.5	.3	80.3	5.0	6.1	91.1
Germany, Federal Republic of	1,518	17.9	33.1	25.4	8.4	1.1	85.9	3.7	.4	90.0	7.1	5.8	102.5
India	610	14.6	29.3	33.1	8.4	NA	85.4	2.4	.1	87.9	3.6	4.0	95.4
Italy	499	18.7	34.0	21.2	8.0	.3	82.2	4.3	.4	86.9	4.7	5.5	96.7
Norway	1,624	17.5	30.4	11.3	6.4	1.2	66.8	3.1	.2	70.1	5.6	5.3	80.8
Spain	681	10.3	38.0	25.7	7.6	.1	81.7	3.6	.1	85.4	2.2	5.2	92.7
Switerland	126	18.6	25.8	15.0	7.4	2.2	69.0	6.2	.3	75.5	2.9	7.4	85.5
United Kingdom	571	13.4	37.2	21.7	7.5	.9	80.7	3.2	.2	84.1	2.9	5.3	92.1
United States	579	12.8	21.5	20.7	6.5	.7	62.2	1.7	.7	64.6	2.5	3.7	70.1
Total or average[6]	26,840	11.2	25.4	16.5	5.6	.7	59.4	3.0	.6	63.0	5.2	5.6	73.2
Nonproducing operations:													
Total or average[6]	2,410	9.9	28.6	10.4	4.7	.4	54.0	.2	3.2	57.4	30.8	26.7	111.7
All operations:													
Total or average[6]	29,250	11.1	25.6	16.0	5.6	.7	59.0	2.8	.8	62.6	7.1	8.5	77.4

NA Not available.

[1] Based on total recovered aluminum divided by life of smelter.

[2] Costs may not total because of individual rounding.

[3] Discounted Cash Flow Rate of Return.

[4] Taxes at 15% reflect higher revenues needed to obtain 15% return on investment.

[5] Total cost (15%) = Total cost (0%) + (taxes (15%) − taxes (0%)) + return on investment.

[6] Reported figures are totals or weighted averages of all operations considered in this study. Other countries include Argentina, Austria, Bahrain, Greece, Iceland, Indonesia, Iran, Mexico, the Netherlands, New Zealand, Qatar, Suriname, Turkey, the United Arab Emirates, and Venezuela.

Source: Bureau of Mines, Minerals Availability Field Office, Denver, CO.